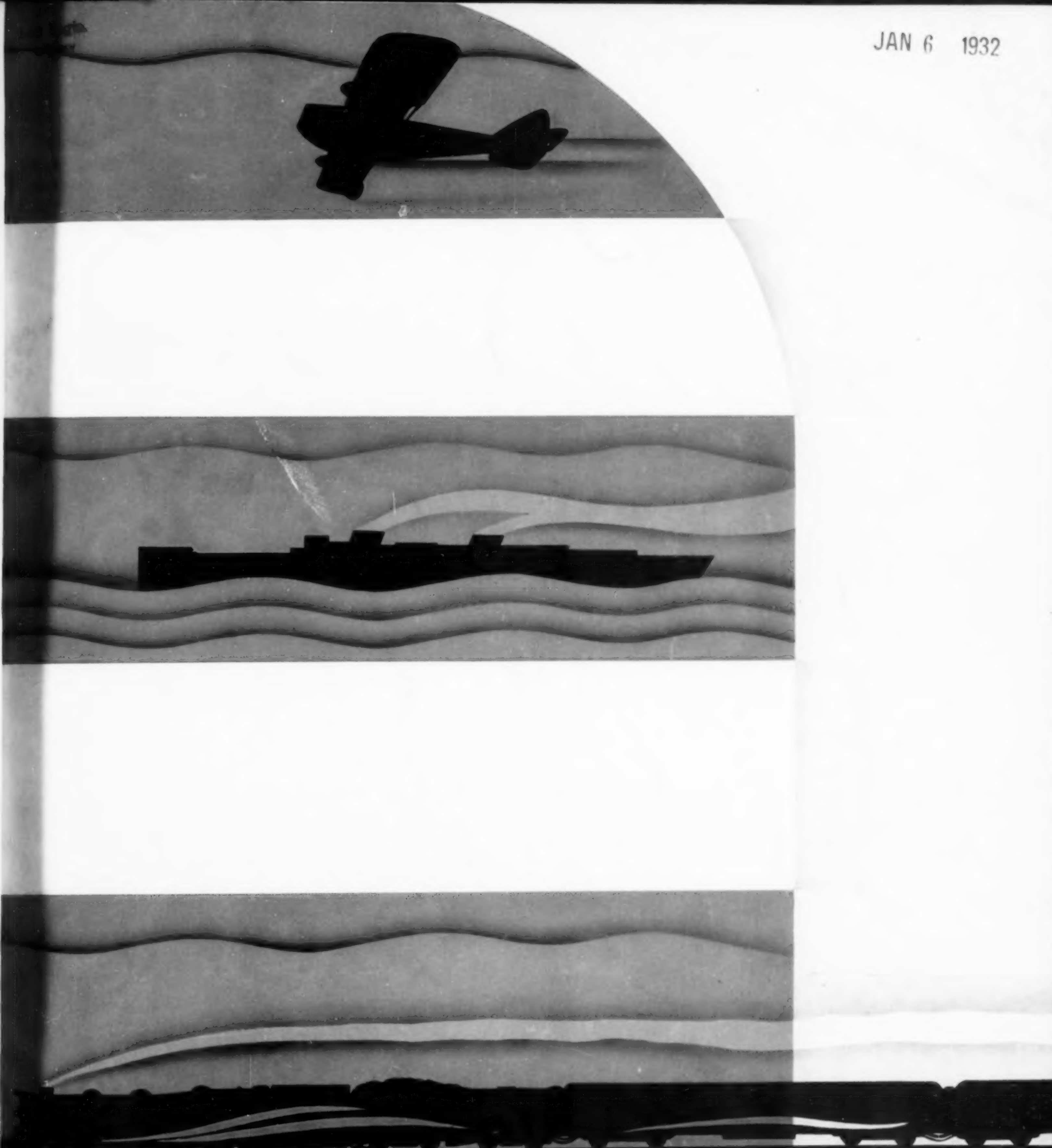

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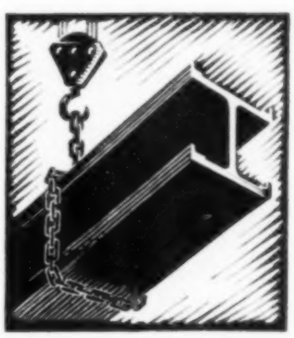

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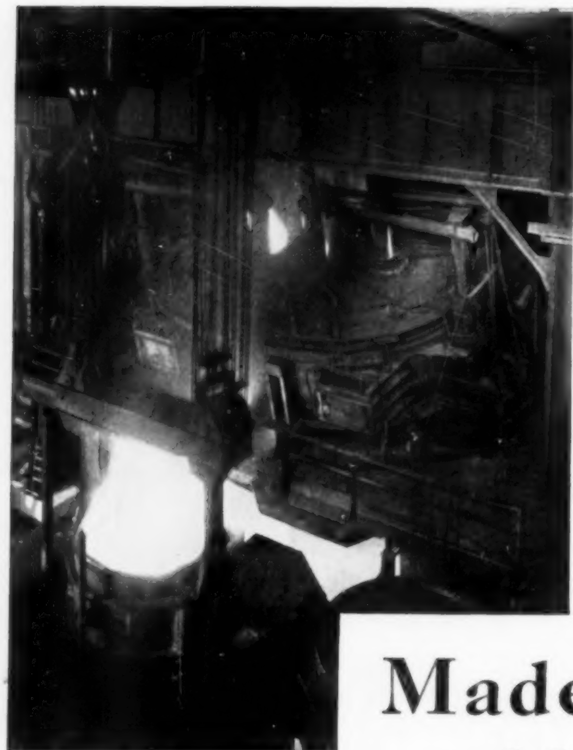

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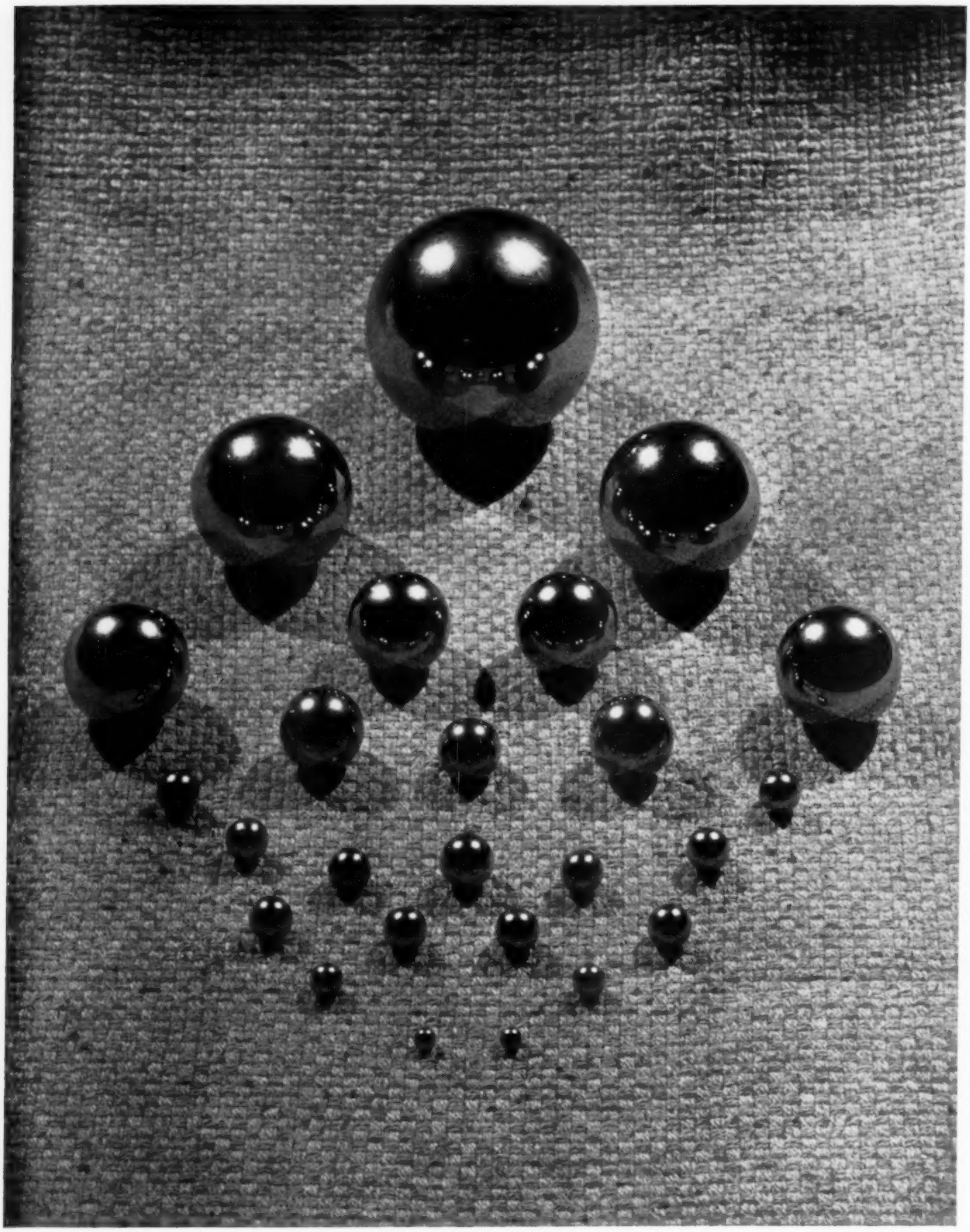


OIL WELL VALVES USE HIGH CARBON STAINLESS BALLS

By H. T. Morton
and I. A. Rummler
Hoover Steel Ball Co.
Ann Arbor, Mich.

WHEN high carbon, high chromium stainless steels are mentioned, one ordinarily thinks of the cutlery steels (say, 0.65% C, 16.5% Cr), but there is another even higher alloy (1.0 to 1.1% C, 17.0 to 17.5% Cr) which has been very useful in the oil industry, in services where a hard metal highly resistant to corrosion is needed. Representative uses are for needle valves and check valves in oil lines.

Working parts of ball and seat valves used in pumps and oil wells are assembled as shown on the next page. Both parts are encased in a pipe through which the oil flows after passing the ball and seat. The action of the pump sucks the oil upward and raises the ball. On the return stroke of the pump the weight of the oil above forces the ball back on its seat, thereby closing the valve. This action is repeated at every stroke of the pump, and the effect on the ball and seat is very similar to impact testing, where a weight continually drops on the test specimen. It goes without saying that the parts must have a high impact value for long service.

Fatigue failures cause flaking and cracking. Other troubles arise from corrosion from brines, or erosion from grit. Toughness, strength, hardness, and corrosion resistance are all required, a rather difficult combination, but one which is successfully met by this 1% carbon, 17% chromium steel when its manufacture and heat treatment are very carefully controlled. This paper will describe some of the early troubles encountered, and the steps taken to correct them. Members of the staff of Ludlum Steel Co. and Firth-Sterling Steel Co. have given many valuable suggestions.

Erosion

Erosion causes the surface of the balls and seats to wear away gradually. Most crude oils and some refined oils contain fine particles of solid matter, sand, or grit, which act as an abrasive when moved rapidly across a metal surface. As soon as a small spot is worn away, the valve will leak — thereby causing increased leakage of oil and more rapid erosion, a vicious cycle. The rapidity of wear depends upon the polish and hardness of the metal itself; soft areas and pitted or defective areas will wear

Full Size View of Small Check Valve for Oil Pumps. This assembly is placed inside the larger well casing; oil sucked up through the inner pipe raises the ball from its seat during a half-stroke of the pump

more rapidly. Therefore, to keep the wear at a minimum, a stainless steel of maximum uniform hardness consistent with other properties is needed. This steel develops and retains a hardness of Rockwell C-56 to C-60 after quenching and drawing. However, even this is insufficient to withstand certain scouring action, as is seen by the view of a ball which has had its surface gouged into grooves.

Corrosion

There is very little atmospheric corrosion of valves used in well casings because most of them are located far below ground level. But the acids or brines contained in most crude oils rapidly corrode ordinary steels, and slowly attack stainless steels. Where ordinary carbon steels become pitted and corroded on all exposed surfaces, the failure of stainless steel parts by corrosion is often confined to small areas on the surface, while the remaining areas might remain bright and shiny.

This localized corrosion occurs frequently when stainless steel parts are left exposed to the elements. J. H. G. Monypenny, on page 175 of his book, "Stainless Iron and Steel," notes that long exposure to industrial atmosphere will discolor a polished stainless steel, and when cleaned its surface is found to be dulled by a multitude of minute pits. Four causes of accelerated attack by corroding media were cited by Dr. W. H. Hatfield in the 1928 Campbell Memorial Lecture, two of which have to do with discontinuities in the metal itself.

Corrosion pits are found in stainless steel balls and valve seats; typical examples are shown at the bottom of the opposite page. A ball with a large corrosion hole similar to those shown was filed to determine the approximate depth of corrosion. After approximately $\frac{1}{32}$ in. was removed from the surface, the bottom had not yet been reached. These pits are very distinct against the bright and shiny ball surfaces; they are sometimes circular patches, but appear more generally as long, thin lines on the surface, difficult to photograph. By etching corroded balls, similar to those shown, with 50% boiling hydrochloric for 10 min. or more, it was found that the long, thin pits were on the sides of the ball extending toward the poles, and the circular pits were at or near the poles of the balls.

(These balls are forged by upsetting hot slugs from round bars smaller in diameter than the finished balls. The areas where the ends of the original bars come to the surface of the balls are called poles. The flash between the dies is the equator, and the area between these sections is called the sides of the ball.)

The long, thin pits extending along lines connecting the poles indicated that there might be a relationship between them and the direction of rolling of the original bars.

Other balls suffering from deep corrosion

Ball Taken From Check Valve After It Had Been Badly Eroded Along Contact Line With Seat by Fine Particles Carried in the Oil

failures were etched and showed the "grain" of the ball to lie parallel to the direction of the long pits on the corroded balls. It was thought that these pits might be seams which had escaped the inspectors. Accordingly, some balls known to be seamy were taken from inspection and etched. Besides the seams marked by the inspectors, other short, shallow marks were developed, resembling hairlines; they were quite different from seams found on balls made from seamy bars of steel.

One lot of these seamy, stainless steel balls was reduced $\frac{1}{16}$ in. diameter, which should have removed all surface defects. The inspectors again picked out seamy balls, and etched samples still showed numerous hairlines. This indicated that the cause of the corrosion pits was an internal defect in the steel and not a surface defect from the bars.

To verify further this fact, a ball containing two hairlines, separated by only a short, smooth surface between their near ends, was filed at this point. After etching, both hairlines were plainly visible on the filed area. Other balls showed these hairlines after filing and before etching. This substantiated the theory that the cause of the pitting was in the steel before the balls were made.

To make sure of the latter statement, disks were cut from numerous stainless steel bars, polished and etched 10 min. in boiling 50% hydrochloric acid. Two of the disks shown on the following page are from a group of bad bars which were forged into balls, finished and inspected in the usual manner. Twenty per cent of the balls from this lot was picked out as seamy. Others which passed the inspectors were found to contain hairlines after etching. A disk typical of those from a group of good bars is also photographed. These were specially picked out and run as were the others; only a negligible quantity of these balls was discarded as seamy. This clearly proved the relationship between hairlines in stainless steel, the seams on the balls, and the pitted corrosion failure of the finished balls.

Similar conclusions as to the cause of pitting and localized corrosion failure are drawn by Dr. Hatfield when he said in the Campbell lecture: "May it not be that iron protects itself by immediately forming the protective film when brought in contact with certain oxidizing media, and that failure to resist, that is, progressive 'oxidation,' results from the puncturing and local destruction of this film through va-

Pitted Balls From Oil Pump. Circular pitted areas occur near "poles" of the ball — that is, at the axis of the original upset bar

Deep Etched Stainless Steel Bars. The two small ones are of bars which will produce a large proportion of balls rejected by inspectors as "seamy." The large bar produces balls free from hairlines or other defects. Natural size

rious causes — from causes such as the presence of particles of foreign matter leading to damage through local electrolytic effects; from local concentration of corroding media in dew effects, etc. Incidentally, a continuous protective film presupposes a continuous metallic surface for it to form upon, and what with the dispersion of oxide or silicate inclusions of indeterminate composition, and the actual unsoundness of the bulk of steel produced, even in America, it cannot be considered that such a condition is fulfilled. The author is of the opinion that ordinary commercial steel can, in itself, be much improved as regards its resistance to corrosion by the extension of our knowledge and application of the laws of physical chemistry where they bear upon steel production from the standpoint of the manufacture of material free from oxides and gas holes."

This matter of porosity and hairlines was taken up with the stainless steel manufacturers, who immediately did intensive research work on the problem. By changing various items in their melting, raw materials, and general practice, a big improvement was made in the quality of stainless steel produced. Hairlines have been so decreased in size and number that they are found only occasionally after deep etching or very careful polishing. By decreasing these heterogeneous areas in the stainless steel, the number of centers for localized corrosion is decreased and the life of the metal is thereby increased.

Heavy pitted areas occurring at the poles might be due to segregated centers in the original bars, so several pitted balls were cut through the pitted areas, given a light etch, and examined. These longitudinal sections showed segregated areas along the centers of the balls connecting the two poles. Steel bars that showed segregation on etched disks were also cut longitudinally through these areas, and showed a line of segregation through them which was very similar to the segregated area of the balls corroded near the poles.

This indicated that segregation is another cause for corrosion and must be eliminated from the stainless steel bars.

Occasionally, corroded balls have a mottled surface appearance not following any distinct pattern. This is caused by failure to remove sufficient material from the surface of the balls after heat treatment. Scaled areas, or metal just beneath scaled areas, have a different elec-

trolytic potential from the balance of the ball and act as centers for localized corrosion.

As noted at the outset, some balls and seats fail from fatigue. A ball of this sort will crack normal to the surface, or certain patches will flake off. Cure for the trouble is a steel of high impact resistance; that is, a clean, sound steel properly heat treated.

Flaking and Cracking

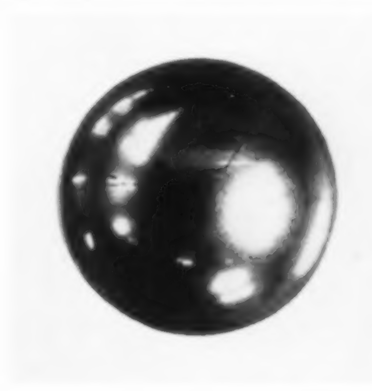
Abusive heat treatment and forging practice do cause cracking and flaking, but this is inexcusable. Since hardness, ultimate strength, and endurance limits are interrelated, the high hardness of the heat treated balls (Rockwell C-58) should imply a high strength and resistance to fatigue. A bright, flaky, coarse-grained fracture may be set down as due to overheating during forging operations. It goes without saying that proper control of temperatures during the forging and heat treating operations is the first essential in manufacture of such parts as those under consideration. Internal defects in the steel and surface corrosion lower the expected endurance values to figures which allow the balls to crack and flake. Some balls that flaked in service were photographed — they have distinct lines through the centers of the flaked areas. Careful examination shows these to be the hairlines described above; they are elongated blow-holes or else contain material which etches out readily or can be filed out. Besides being a nucleus for corrosion failure, they appear to weaken the metal when they occur sufficiently near the surface of the balls to cause flaking.

A view is shown at right of a ball which cracked in service. This ball had numerous small corrosion pits on its surface. On testing, it showed good, fine-grained fracture, indicating proper heat treatment. Other than the corrosion pits, no defects were found which should cause the cracking.

This failure was attributed to corrosion fatigue, which was studied by D. J. McAdam, Jr. and some others, and it is well established that mild corrosion causes the early breakdown of fatigue specimens. For instance, a 0.47% carbon steel, with a fatigue limit of 60,500 lb. per sq.in. in air, had only 20,000 in a stream of hydrant water. T. S. Fuller shows how stainless irons used for turbine blades have fatigue limits cut in half by wet steam (Metal Progress for July). In searching for a reason for this phenomenon, the following words, which Albert Portevin wrote in *Revue de Métallurgie*, November, 1929, may be indicative: "Localized corrosion is characterized by non-uniform depth of attack and cannot be defined by the loss per unit of area. Internal corrosion does not destroy the surface of an object but results in a layer of corroded metal underlying the surface and having no strength. The corrosion medium travels along the grain boundaries affecting some of the constituents and leaving others intact, or depositing on them the products of the reaction. Without any change in dimension, loss of weight, or properties determinable by tensile testing, a metal may become very brittle, often only temporarily. This phenomenon is usually associated with the generation of nascent hydrogen on the surface of the metal."

As stated by Portevin, corrosion may weaken a ball by decreasing its cross-sectional area, by weakening the intercrystalline strength, or by the generation of nascent hydrogen. Failure of stainless steel parts by cracking and flaking is closely linked with corrosion failures and requires homogeneous material free from internal defects to give it a high corrosion resistance, and proper heat treatment to give it maximum strength or impact resistance for its particular application.

Typical Corrosion Fatigue Crack. Ball is still bright, having resisted corrosion over its surface except at a few localized areas



By G. M. Rollason
Vice-President
The U. S. Aluminum Co.
and Sam Tour
Vice-President
Lucius Pitkin, Inc.

MODERN DIE CASTINGS OF ALUMINUM . . . .

IN DIE CASTING, a hydrostatic pressure (usually above 100 lb. per sq.in.) is applied to molten metal to force it into and hold it in the cavity of a metallic mold or "die" until solidified. This involves specialized equipment and results in a product sharply differentiated from that of any other casting process.

The special characteristics of die castings offer a number of economic benefits where a metallic piece is used in large quantities.

1. The die casting process affords a means of producing pieces at a rapid rate with uniformity of material, appearance, and dimension.

2. It reduces or totally eliminates machining operations, because of the dimensional accuracy of the product and the ability to cast threads and core holes.

3. Different kinds of metal may be cast into position, as studs, bushings, and inserts.

4. Castings may have thin and light sections.

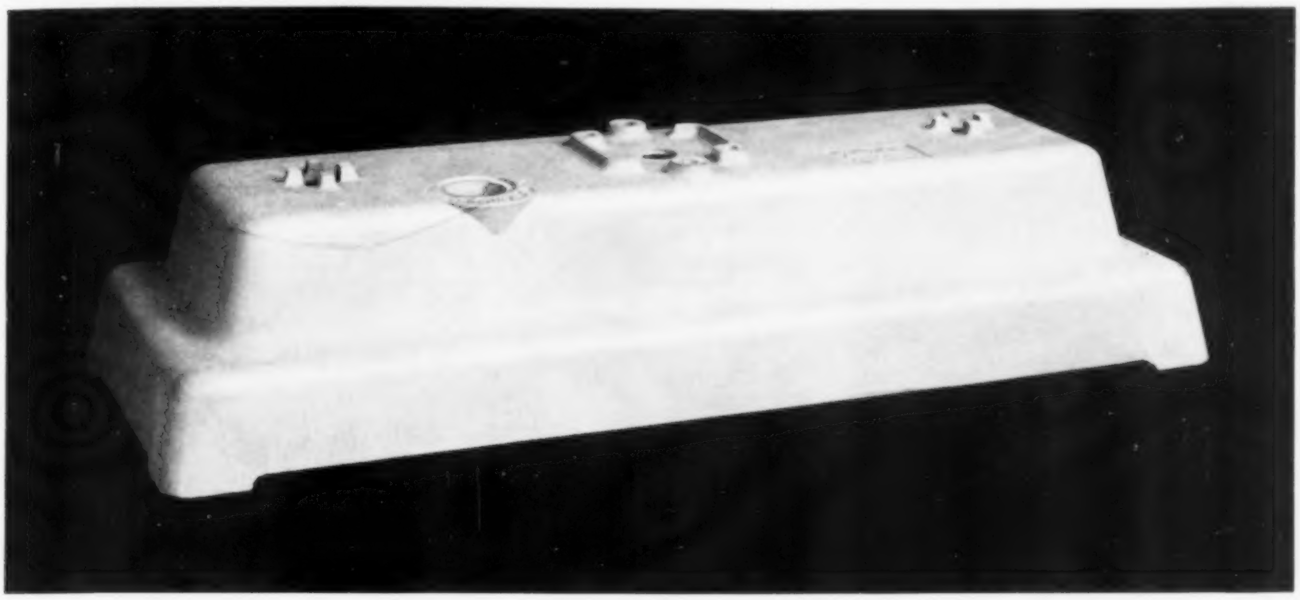
5. Pieces made by assembly of sheet metal or stampings can be reproduced as one die casting, where the integral construction gives greater strength and rigidity at considerably lower cost per piece without the need of an expensive series of punching, forming, and drawing dies, and other jigs and fixtures.

6. Die castings have smooth surfaces; finishing operations are cheap.

7. Engraved or ornamental designs are accurately reproduced in quantity at low cost.

The initial cost of aluminum die castings is slightly more than that of other common white metal die castings. To offset this cost differential, aluminum alloy die castings offer the advantages of light weight, superior resistance to corrosion, resistance to the effect of moderately elevated temperature, and a higher degree of permanency of dimension and shape.

Based on these characteristics, they have been commercially applied for household utensils and appliances, for automobile hardware and parts such as brake shoes, brackets, hous-



Commercial Sizes Are Constantly Increasing. This motor base, by no means the limit, measures 4-1/2 x 8 x 21 in., and has an average wall of 0.11 in. Some castings have been made over 40 in. long

ings, pump and carburetor bodies, for airplane engine parts, portable tools, electrical equipment, radio parts, and for cases and frames for instruments.

Scope and Limitations

In considering the use of die castings, the following characteristics should serve as a guide, but in complicated, elaborate, or doubtful cases, advantage should be taken of the experience of an engineer specializing in die castings.

Size. In 1930, aluminum die castings were commercially produced weighing 11 lb. with over-all dimensions approximately 20x15x9 in. Dimensions in one direction may exceed these considerably; castings have been made over 40 in. long — 25 in. is quite common. The minimum limit of size depends on economy and dimensional accuracy; for very small work, stampings or screw machine products should be considered as alternative materials.

Section Thickness. On large castings, metal thickness can be reduced to 0.090 to 0.100 in. Sections less than 6 in. in length or width may run as low as 0.060 to 0.075 in. It is usually desirable to keep wall thickness fairly uniform (or, at least, to avoid abrupt changes in thickness) and to keep sections as light as consistent with the requirements of strength and torsional rigidity.

Prepared for Non-Ferrous Data Sheet Committee of Institute of Metals Division of the A. I. M. E. and the Recommended Practice Committee of the A. S. S. T.

Dimensional Accuracy. Commercial aluminum die castings are generally produced to tolerance limits of plus or minus 0.0015 in. per linear inch. When once the shrinkage of a particular casting has been determined by successive trial and reworking of the dies, much closer limits can be maintained on dimensions of 3 in. or more. Each job must be engineered with specific tolerances in mind.

Dimensions measured perpendicular to the parting line are maintained within limits of minus nothing plus 0.010 in. in the largest casting, down to minus nothing plus 0.003 in. on small pieces. Die castings have been produced for special purposes in commercial quantities with limits of plus or minus 0.001 in. across the parting line, but such close tolerances are not generally specified or met.

Cores. Coring of required holes or cavities not only reduces machining operations, but saves metal weight and permits the beneficial chilling action of the steel cores to be exerted

throughout a greater part of the casting. Slight drafts are used to permit withdrawal without injury to core or casting. Small holes for tapping are usually cast to root diameter of thread with standard draft added. Standard drafts are as follows, expressed in the amount of draft per inch of depth. (These figures may be reduced but will probably involve more frequent replacement of cores.) For holes less than 1/8 in. the draft is 0.015 to 0.020 in. on diameter; for 1/8 to 1 in., draft is 0.010 in. on diameter; and cores more than 1 in. require 0.010 to 0.030 in. on diameter, depending on size and design.

Three Alloy Systems

The great bulk of aluminum alloys used in die castings falls into three main groups: (1) Aluminum-copper alloys, (2) aluminum-silicon alloys, and (3) aluminum-copper-silicon alloys with or without further additions of nickel or other elements.

Copper is added in amounts varying from 4 to 14% (occasionally higher). Increasing additions of copper render the resulting alloys progressively harder and less ductile, and at the same time lower the melting point, increase fluidity, reduce shrinkage, and thereby improve the casting properties up to the point where excessive hot shortness makes it impossible to eject the casting from the die without breakage. Copper has a tendency to reduce the corrosion resistance of aluminum.

Silicon is added in amounts varying from 5 to 13%. Increasing additions of silicon progressively harden the alloy and improve casting properties. At the same time corrosion resistance is maintained.

Ease of casting increases with additions of silicon up to the eutectic composition, which is 11.6% silicon (both with and without the presence of commercial amounts of iron). A 10 to 12% silicon composition is widely used. Although the chill resulting from dies or permanent molds probably displaces the eutectic composition and temperature to the "modified" eutectic point (13 to 14% Si), commercial die castings with 13% silicon may show some free silicon (with consequent decrease in ductility) at points where the chilling is, for some reason, insufficient. Free silicon is much less evident in alloys with silicon from 11 to 12.3%, and the casting and physical properties of such alloys are entirely satisfactory.

The improvements in physical properties of sand-cast aluminum-silicon alloys obtainable by "modification" before casting, and heat treatment after casting, have been frequently described. In die casting practice, such modification by special fluxes or reagents is not necessary nor even beneficial, because the rate of solidification is sufficiently rapid to produce a fine grain.

Heat treatment of aluminum-silicon die castings is rather seldom done, and is confined to annealing (heating for 1 to 2 hr. at 750° F., followed by slow cooling). This increases ductility at the expense of tensile strength. A typical effect is to reduce the Brinell hardness on a relatively thin section from an average of 93 to around 65.

Aluminum-silicon alloys combine advantages in casting properties and corrosion resistance over the series of aluminum-copper alloys, but the latter are occasionally preferred for special purposes such as ease of machining and for their brighter color. Silicon imparts a slightly bluish tinge. The aluminum-silicon-copper series, therefore, has been a natural and successful result of efforts to combine the advantages of both the preceding types. Nickel additions are especially useful in brightening the color. A comparatively large number of analyses used in commercial practice is largely a reflection of varying individual preferences among manufacturers and users. Some typical alloys are given in the table.

Impurities in the Alloys

Alloys of aluminum with one or more of the elements copper, silicon, and nickel cover all but an insignificant percentage of present commercial alloys. Other elements such as manganese, magnesium, iron (except where present in small amounts as impurities) are not usually introduced. Zinc is frequently used, and tin occasionally, as additions to sand-cast alloys, but they are rarely used for die castings, as both elements produce hot shortness, thereby impairing the casting properties without benefiting the mechanical properties. Furthermore,

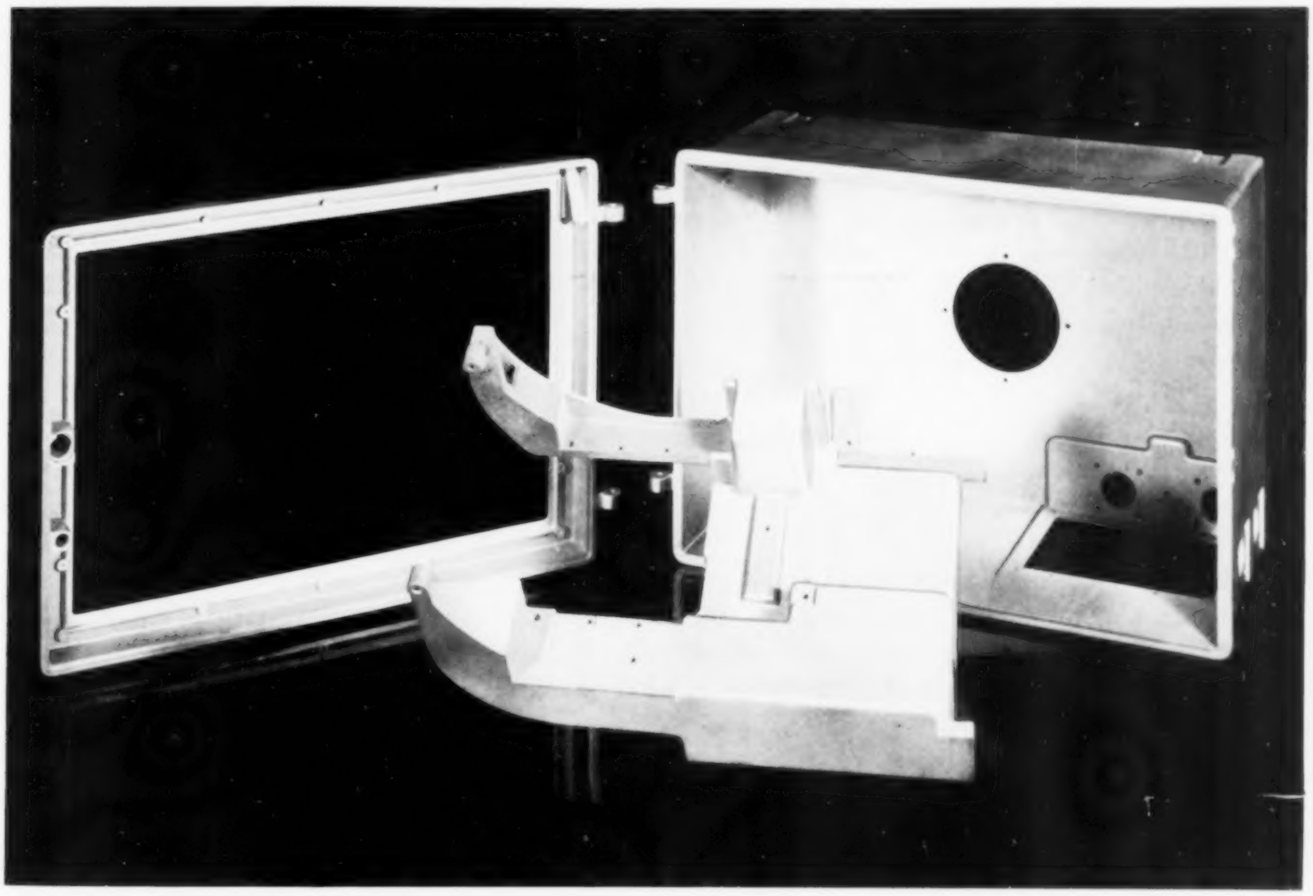
zinc tends to lower corrosion resistance; it is undesirable in amounts exceeding 1.0% and is preferably kept below 0.75%. More than 1.0% leads to the suspicion that low grade aluminum scrap has been used by the manufacturer.

Commercial aluminum die castings usually contain more than 1% of iron regardless of the original source of the raw material; it is absorbed by the molten alloy from the melting pot and other parts of the machine. Iron acts as a hardener in all the alloys shown in the table. The working range may be considered as 1 to 2% for iron; a larger percentage causes the alloy to become sluggish in the casting operation and brittle in the finished product. Manganese has an effect somewhat similar to iron, but 0.75% or less is of some slight advantage to aluminum-silicon alloys in counteracting the coarsening and embrittling effect of excessive iron. At times, small additions of chromium are put into the alloy for the same purpose.

Nickel is not regarded as a harmful ingredient in the alloys containing copper.

Good grades of secondary or scrap aluminum may be used in the preparation of the alloys in admixture with primary metals, but only when the mixture is properly controlled by analysis. Good clean sheet clippings, or the equivalent, constitute an excellent source of secondary aluminum, their form being evidence of a clean history. In general, the desirability of aluminum scrap for this purpose decreases steadily with repeated remeltings.

Case, Cover and Frame for Potentiometer Pyrometer Illustrate Intricacy of Designs Die Cast of Aluminum Alloys. One contains many holes, cored in three directions



Typical Commercial Alloys

Selection of aluminum die castings for various purposes has resulted in wide variety of alloys. A committee of the American Society for Testing Materials has conducted an extended

PROPERTIES OF ALUMINUM DIE CASTING ALLOYS

A.S.T.M. No.	Class	Nominal Composition, Per Cent				Tensile Properties of 1/4" Diameter Round Specimen		Charpy Impact Strength of 1/4" Square Specimen	Specific Gravity
		Copper	Silicon	Nickel	Aluminum	Ultimate Strength Lb. per Sq. In.	Elongation in 2 In.		
4	Al-Si	–	5	–	Balance	29,000	3.5%	4.5 ft-lb.	2.70
5	Series	–	12	–	Balance	33,000	1.5	2.0	2.66
6	Al-Cu-Si	2	3	–	Balance	30,000	3.5	5.0	2.75
7	Series	4	5	–	Balance	32,000	2.0	2.5	2.78
8	Al-Cu-Si-Ni	1.5	1.5	2.25	Balance	29,000	4.0	4.5	2.72
9	Series	4	1.75	4	Balance	31,000	1.5	2.0	2.87
12	Al-Cu	8	1.5	–	Balance	33,000	1.0	1.5	2.85

program of tests on 12 typical ones. Seven of them, as given in the table, are quite representative of the range of present commercial practice, it being understood that compositions may vary somewhat from those in the table according to particular requirements. Some of the compositions are patented, but are being used by numerous firms under licensing arrangements which offer no restriction to their availability.

Numbers 4, 5, 9, and 12 are probably the most extensively used, but the others, together with slight variations or combinations, have many applications.

It should be thoroughly understood that the mechanical properties quoted for die casting alloys are usually based on special test bar specimens. Differences of several thousand pounds per square inch are found between flat test specimens 1/8 by 1/2 in. in the reduced section and round test specimens 1/4 in. diameter in the reduced section. Individual specimens cut from die castings give widely different results, depending on the thickness of the wall and the manufacturing practice. Results of tension and impact tests on die-cast bars, tested without machining, as given in the table, are most useful as a comparison of the physical properties of different compositions in pressure-cast test pieces under identical conditions.

Selection of alloy for a given die casting depends largely on the type, size, and use of the casting. In addition to casting and physical properties, consideration must often be given to such items as color, machinability, ease of plating, surface hardness, and resistance to corrosion.

Extensive machining operations on die castings are not usually required. Ordinarily, they consist of light turning, reaming, or edge milling, and tapping or milling internal threads. External threads are usually cast with sufficient accuracy to require only light chasing. The general principles of tool design given by R. L. Templin in "National Metals Handbook," 1930 Edition, p. 640, for machining aluminum are applicable.

For turning operations on aluminum-silicon alloys, tool bits or tips of the tungsten carbide materials have been found to last from 10 to 20 times longer without regrinding than the best grades of high speed steel with the same feeds and slightly higher cutting speeds.

Sand blasting can be performed in any standard equipment suitable to the size and quantity of the work. A fine, clean sand should be used (such as No. 1 to 1/2 flint) and renewed frequently to avoid discoloration. A sand blasted surface tends to show finger prints and other handling stains, which can be overcome by dipping into a thin oil. Sand blasting forms an excellent preparation for painting, enameling, and lacquering.

Paint and lacquer can be applied by standard methods of spraying, brushing, or dipping. The only necessary precaution is to clean the surface by sand blasting or washing with commercial cleaners. If cleaning is not feasible, use a priming coat of asphaltum-base paint.

Scratch brushing produces a satin finish similar in appearance to roughly etched glass; it is accomplished by a revolving wire brush. Castings should be thoroughly cleaned of oil or dirt. The most satisfactory scratch brush finish is obtained on castings which have been first dipped in an alkaline solution and then in acid.

Bright dipping imparts a dull white, somewhat satiny appearance to various fabricated forms of aluminum, including die castings. Since the alloys usually contain a certain percentage of added silicon, it is necessary (after etching the castings with caustic or alkaline

cleaning solution) that the acid bath used for brightening should dissolve the silicon set free or exposed by the etch. The best mixture is of hydrofluoric and nitric acids in a dipping tank lined with pure sheet lead. A muriatic-nitric acid mixture is commonly used for aluminum sheets and aluminum-copper alloy castings. Unsatisfactory bright dipping operations are sometimes attributable to the use of muriatic instead of hydrofluoric acid on aluminum-silicon alloys, the use of the acid in a stone crock or the like, the use of acid which has become neutralized or diluted or which has a top coating of oil accumulated by dipping improperly cleaned castings. In handling the hydrofluoric-nitric acid mixture, great care must be exercised not only to protect clothing but to avoid severe acid burns.

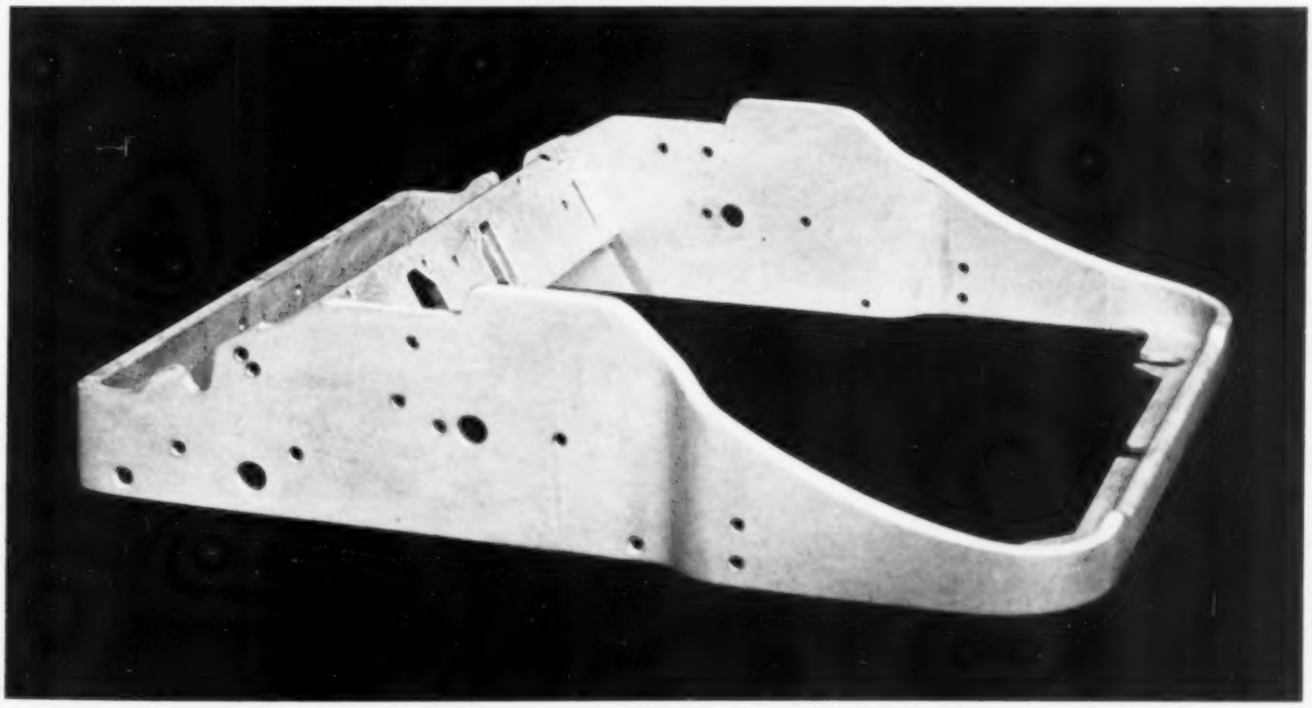
Ball burnishing affords a highly economical means of putting a satisfactory finish on small die castings, although it is not equal to the regular emery, polish, and color-buff operations. The castings are agitated in a wood-lined barrel with a soap solution and steel balls.

Polishing operations impart the highest degree of mirror-like finish to vacuum cleaner parts, domestic utensils, and ornamental work. A sequence of four will give excellent results: (1) Emery on a glued rag wheel, (2) emery on a felt wheel, (3) buff on a stitched rag wheel, and (4) color on a built-up rag wheel.

The first emery operation may be conducted with No. 100 emery or coarser, depending on the amount of preliminary dressing necessary to remove nicks, scratches, and die checks. Before proceeding to buff and color, the entire surface should be ground with emery of No. 150 grade or finer. On castings with plain, uninterrupted surfaces, the second or felt wheel emery operation can frequently be omitted. Otherwise, it is useful in avoiding "drag marks" due to rag wheels catching in the edge of cored holes. A somewhat lower grade of finish can be accomplished at considerable saving in cost by eliminating the emery operations and simply buffing and coloring.

Plating can be done with any of the common plating metals such as nickel, brass, chromium, and silver. The procedure was described by H. K. Work in METAL PROGRESS for April, 1931.

Oxidized and colored finishes on copper, brass, and silver plated castings can be produced by the same methods commonly employed in obtaining these finishes on the solid metals, or plated base metals other than aluminum. Oxidized finishes should be protected by a thin coat of lacquer.



PRACTICAL IMPORTANCE OF SPECIFICATIONS . . . FOR MATERIALS . . . . .

By H. H. Morgan
Department Manager
Robert W. Hunt Co.
Chicago

AMERICA is the land of the Biggest, the Best, and the Most. We have the biggest buildings, the best mass production methods and the most money. These are the objectives of a new, virile and energetic country and we are that. We play hard and we work hard. When something appeals to us, we take it seriously and generally end up by overdoing it. This applies even to the making of specifications.

Most specifications have their good points — which largely accounts for their present multiplicity. On the other hand, some specifications are bad, and it is primarily the inability to make and use them properly that has prevented many from enjoying the benefits which might come from their use. The importance and, to some extent, the unimportance of specifications are, therefore, the two subjects for this discussion.

The subject is not a new one. It was discussed by Charles B. Dudley, then president of the American Society for Testing Materials, in 1903, in an address before that body, in order to crystallize into definite statements the requirements for good specifications. So well did he accomplish his task that he became recognized as "the father of specifications." Since his day, so many have contributed their ideas that it would obviously be impossible to list and give credit to each. A few, however, may be mentioned: N. F. Harriman, Dean Harvey, and J. W. Bancker. Their contributions have been outstanding — but it should not be thought that they stand alone and unequalled.

As recently as June 25, 1931, a joint meeting of the American Society for Testing Materials and the Western Society of Engineers discussed "The Economic Significance of Specifications for Materials." This was a fresh indication not only of the vital interest the subject held, but also of a developing realization that some sort of rationalization was necessary in order to make clear in the minds of many the practical importance of specifications.

In order to avoid the pitfalls of straying from the subject during the present discussion, it seems best to examine the title critically, with the purpose of definitely fixing our objectives.

The three words which lend import to the title are (1) practical, (2) specifications, and (3)

materials. "Practical" is taken to mean "susceptible of being put into practice, or of serving or helping to attain useful ends." By "specifications" is meant a definition of the buyers' requirements as an adjunct to the purchase order. "Materials" include only the basic elements (such as steel in its various mill forms, cement and similar products) from which capital and consumer goods such as tools, devices, structures, or machinery are created. The title now takes on a definite and limited meaning. It says, essentially, "The importance of having, as an adjunct to a purchase order for the basic elements of industry, a definition of the buyers' requirements which is susceptible of being put into practice and helps to attain useful ends." We must not overlook the fact that nearly all manufacturers of devices, appliances, or equipment are buyers of material. It is also true that the manufacturers of materials are heavy buyers of materials they themselves do not manufacture. The term "buyer" used in this discussion, therefore, applies to every company, corporation, or industry. To see just how specifications are put into practice and what useful ends they serve is the present problem.

Material specifications may be the specifications of an individual buyer, or a group of buyers of one industry, of a trade association, of a technical society — or may be the national joint standard of all industries buying or making the material.

Specifications have a general, or indirect importance, as well as a specific, or direct importance. Indirectly, they tend to separate the significant from the insignificant, the tangible from the intangible, and to provide a common meeting ground for both buyer and seller. Directly, they furnish an efficient and economical basis upon which to deal with materials.

Railroad Organizations Early Recognized the Value of Purchase Under Specifications. Boiler plate, rails, ties, fuel represent a few of the items which may safely be purchased in large quantities from the several convenient sources, because the essential requirements have been reduced to writing

Photo by Rittase

When we speak of the general benefits which accrue through the use of specifications, we mean *good* specifications. Poorly drawn specifications will not, for instance, distinguish between the significant items and those which have no significance. The more one puts into the preparation of specifications the more one gets out of them.

The same remarks apply to the separation of measurable qualities from those which are intangible. Materials are possessed of both qualities, but only those which can in some way be measured are of any value. Likewise, in providing a means by which the buyer and seller may speak the same language, commerce between the two is greatly facilitated, and the way opened for the more specific and direct benefits which a good specification, properly used, might bring to both.

Eight Advantages

These specific advantages of using good specifications may be listed as follows — (1) they enable the buyer to get what he wants; (2) the material is of uniform quality; (3) the buyer receives goods more quickly and with less trouble; (4) he has access to wider markets; (5) costs are lower; (6) a suitable acceptance basis is established; (7) material becomes standardized and (8) research is promoted.

The prime purpose of every specification, whether it be a national standard or that of a single individual, is to enable the buyer to tell the seller precisely what he wants — and then get it. It is for this one reason, and none other, that all specifications are written. It can readily be seen that this is of benefit to both buyer and seller, and that the importance of this aspect cannot be overemphasized.

Not only does the buyer want material of certain qualities, he also wants to be sure of continually receiving goods of uniform quality. Generally his plans are laid, and his machinery set to work on material of unvarying character. Through specifications, the buyer has a control over his material, and by eliminating trouble from this source, his manufacturing processes may proceed according to a predetermined schedule. The supplier on the other hand, assured of a definite demand, may stabilize his operations for an even flow of production. From this follows, in logical order, the third advantage mentioned above — the minimization of delay in securing materials.

Specifications which adequately tell the manufacturer what is wanted, and enable him to take proper steps to supply the demand, avoid many misunderstandings due to inaccurate and inadequate information, which result in delays while correspondence or discussion settles the issue. Material which is unsatisfactory and must be rejected upon receipt is especially expensive, for although the cost is not entered in the company's journal, it exists in the form of delayed production which may amount to more than the original cost of the material itself. One's ability to secure goods of right quality without delay depends not only upon his being able to supply essential information to a certain supplier, but also in being able to choose between a number of manufacturers, scattered perhaps throughout the country. The possibility of choosing from a wide market is still another advantage.

In providing a wide choice of manufacturers from which the prospective purchaser may select one or more to fill his needs, one of the first services rendered is that of sweeping away trade names and other unsatisfactory restrictions. By such devices the buyer is limited by what he knows from experience about a few products; with his choice thus narrowed, he is at the mercy of a few producers. Furthermore, it may be an economic necessity to buy goods from Coast to Coast when plants are scattered throughout the country. In order to save freight rates and delays, it will be necessary for each unit to purchase from those suppliers in its immediate neighborhood. Yet each shop is designed to turn out exactly the same product and, consequently, must be supplied with exactly equivalent material. Specifications assure this wide market of equivalent material.

They go further; they assure it at the lowest possible cost consistent with the quality demand. This possibility of securing low prices is, therefore, another item of practical importance which is attached to the use of specifications. Because the supplier knows what is demanded of him, he can avoid trial-and-error methods in order to meet the buyer's demands. This fact, combined with the consequent stabilization of prod-

Precise Requirements of Electrical Materials Have Been Responsible for Many Widely Used Specifications
Photo by Rittase

uct and producing processes, makes it possible to offer lower prices to the buyer. Not only are actual costs reduced in the manufacture of goods and these savings passed on to the consumer, but the purchaser, having access to a wide and hence competitive market, is enabled to set supplier against supplier by means of instituting competitive bidding. The competing bidders are asked to supply equivalent services and values at prices reflecting their varying degrees of skill and initiative.

The suppliers, in their eagerness to obtain an order, often overestimate their ability to produce goods of a certain quality at the price quoted. Unless specifications are used as a basis of acceptance, the buyer may receive goods of inferior quality from a producer who has over-reached himself.

This provision of a suitable basis upon which to accept goods is another very useful end to which the specification may be put. By stating exactly what testing or analysis is required and to what extent inspection will take place, the producer knows beforehand the standards his product must meet in order to be accepted. The provision for uniform inspection, testing and analysis does away with discrepancies which might and often do cause controversies.

A specification, which by wide use and agreement has become a national standard, is of more importance than one set up by a single buyer. Material manufactured to such a national specification becomes a standard product, known throughout the industries. Manufacturers are prepared to supply it in the most efficient and economical manner, while those who buy know from experience what to expect of the material — its potentialities and limitations — and have built their product around the uniform qualities of the material. The advantages of a wide market, uniform product, quicker and easier deliveries, and lower costs are all open to the user of a national standard.

Application to Specialties

And yet, new specifications by individual buyers are becoming more and more numerous. This is essentially due to the thought that a special use or application justifies certain specialized requirements. The buyer may or may not be justified, but I am inclined to believe that too often he has not recognized the undoubted fact that a material conforming to a specification already written (perhaps a national standard) would be satisfactory for his use with only

minor restrictions on such items as tolerance, workmanship, or finish.

Quite apart from the direct benefits of specifications as just noted, and yet intimately tied up with their use, is their value in promoting research. The buyer (in making a new specification or in considering the value of a national standard) and the seller (attempting to meet the provisions and limitations placed upon his product in the most efficient manner) will both be led to examine critically the product and its possibilities. This research may go only so far as to develop efficiency in handling the product, or it may develop new uses and potentialities hitherto unsuspected. It may even lead to the rejection of one material in favor of another. Regardless of the exact outcome, certain benefits of a permanent nature are sure to result from such investigations.

While this discussion is concerned only with the practical importance of specifications in use and not with their preparation, yet in order to secure the potential advantages they must be properly drawn up. A few words on that subject may not be amiss.

Clarity and Brevity Essential

Above all, specifications should be clear and complete. Ambiguities of meaning or lack of vital requirements or instructions will rob the specification of all its value. On the other hand, severe restrictions should be avoided; limitations, while they may come from chemical analysis, physical tests, microscopic examination, or methods of manufacture, should be governed strictly by the service desired. It is *service* that the buyer wants — not a mass of physical or chemical data.

Clearness, completeness and sane restrictions can be attained only through the joint efforts of buyer and seller. The material has two aspects, both of which must be taken into account — first, the problems of its manufacture; second, its use by the purchaser. Without a clear understanding of both sides, gained only through the cooperation of producer and consumer, incongruities will quite likely appear to wreck all the fondest hopes of the specification writer.

Due to the steady progress of industry, no specification, however well written at the time, can stand long without occasional revision. New products and improved methods of manufacture constantly tend to change the original conditions. Above all, therefore, the specification should be open to revision.

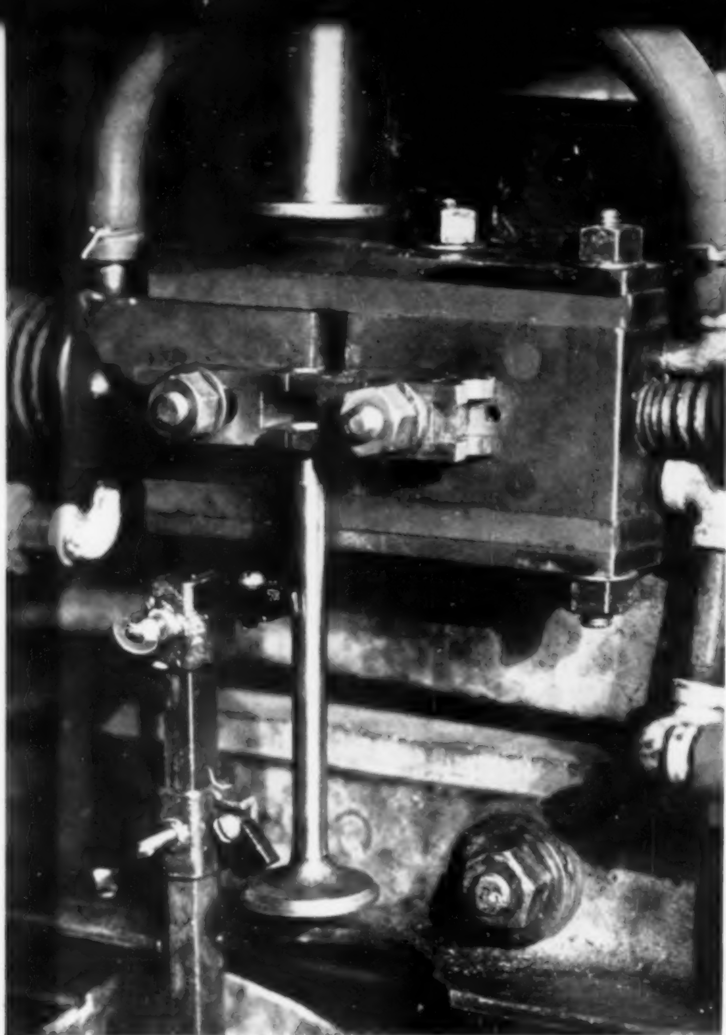
Not only should the specification describe exactly what is wanted, but such qualities as are desired should be subject to tests, analyses and inspection. When these are well known, mention alone is all that is needed, but when new methods are used or different results are expected, adequate descriptions should be included. Inspection by the buyer or his representative is essential if he is to be assured that the tests and analyses are impartially made.

Method of Enforcement

The extent to which material should be subjected to inspection should be clearly stated, and this, in turn, depends largely on its importance. If the material is ordered in large quantities or if its failure in service would mean costly delays in production or loss of life or money, then constant and rigid inspection should be employed. Wherever practicable this should be performed at the point of manufacture. On relatively unimportant material bought in small quantities, less frequent inspection is needed.

To sum up: The practical importance of specifications hinges directly on their ability to assure the buyer he is receiving exactly the goods he orders. In the competition of trade, particularly in regard to heavy products under mass production, it is essential to know that materials are furnished according to specifications. Adequate specifications for materials with competent inspection assure to the buyer a maximum usefulness and serviceability of material at a minimum of cost. The efficiency of any organization is measured thereby.

While a large percentage of buyers cannot maintain the expert personnel or research facilities to write adequate specifications, all want to increase their efficiency. They can do this by utilizing standard specifications, materials, and the facilities afforded by research institutes and commercial testing laboratories organized for this purpose.



ELECTRIC EYE MEANS ACCURATE HEAT TREATMENT

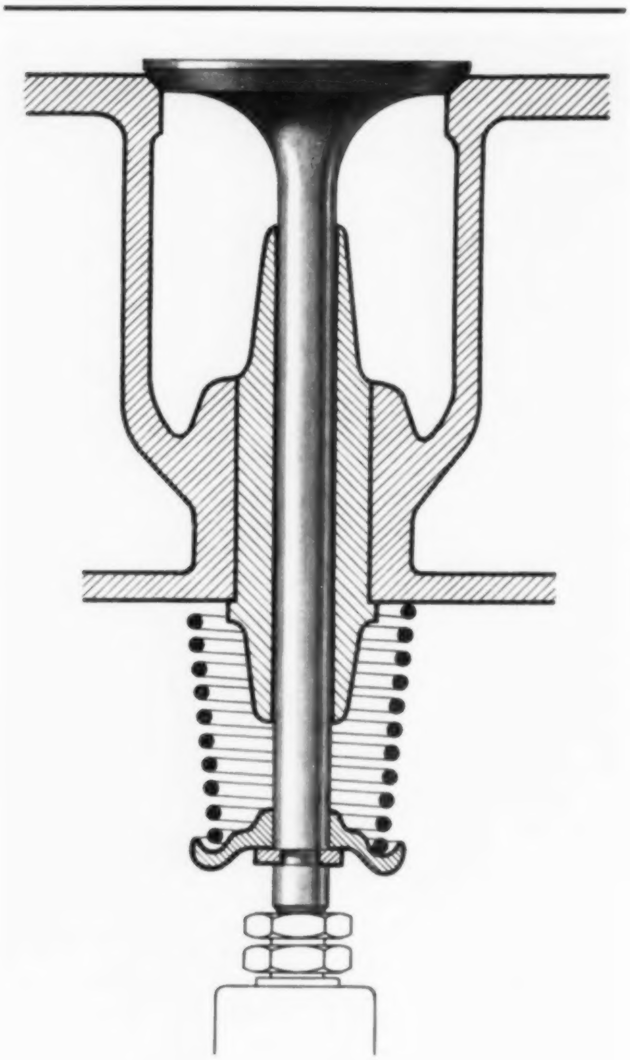
THE electric eyes have it! The marked superiority of the photo-electric cell over the human eye in measuring light intensity and color has won for it a place in steel treating.

Thompson Products Co., Cleveland, manufacturer of valves for aircraft and automobiles, has for a long time hardened the tip ends of automobile valve stems where they ride on the tappets. (A drawing on the following page shows the valve mechanism of a typical automobile valve. The hardened tip of the valve is shown in the lower part of the sketch, just below the spring and spring clip. The tappet, surmounted with a pair of adjustable lock nuts, is just below it; proper clearance between the valve and the tappet is made by these hardened nuts.) With every revolution of the camshaft, the tappet is raised, which in turn lifts the valve to the open position. As the cam turns, the spring closes the valve. A soft tip on the valve would soon mushroom and disturb the delicate adjustment in clearance.

The localized heating required to harden these tips was formerly done by two men. One of them set the valves tip-end up in clamps at the bottom of a revolving circular tank filled with soluble oil to a level which exposed only the tips. The second man heated these tips with an oxy-acetylene blowpipe as they came by. His eye was the only gage of temperature, and his experience had to be considerable, for there was a difference of 425° F. in the hardening temperatures of the various air-hardening valve steels used.

Production of these two men was somewhat over 500 valve tips hardened per hr. Compressed gas cost about $14.00 in a nine-hour working day.

Substitution of automatically controlled electric heat for the blowpipe and of the electric eye for the human eye has increased production slightly (to about 550 per hr.) but now one man is able to do all the work. Further advantages consist of a total cost of 8¢ for the



Typical Automobile Valve Mechanism

avoided. Electrodes are machined in several standard sizes and can be installed on the machine in a minimum of time to accommodate valves of various dimensions.

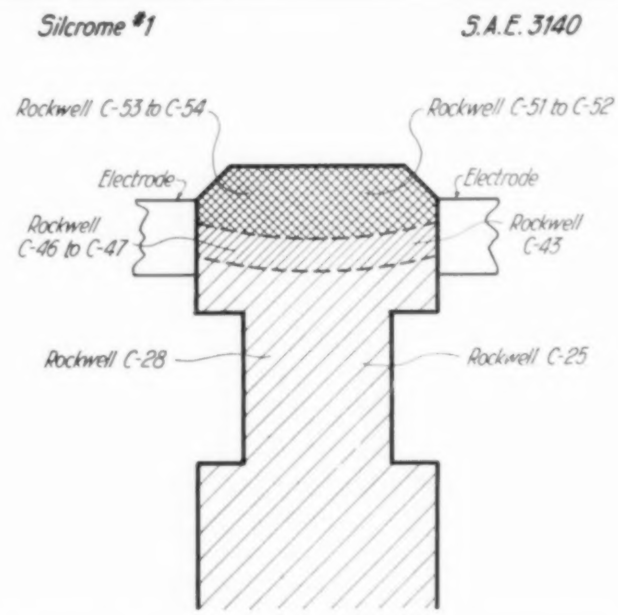
The operator has merely to insert the valve in the jig and press a button which starts a current of 2000 amp. at one volt, through the electrodes. The heating apparatus is very similar to a resistance welding machine, consisting, as it does, of electrodes for carrying a current which comes from a transformer giving the necessary high amperage and low voltage. The valve tip heats fast, reaching a visible red in less than a second. When a certain color is attained, the photo-electric cell opens a sensitive relay. This, in turn, opens the main line relay, which cuts off the current on the heating medium and at the same time opens the jaws of the electrode. The valve then drops of its own weight down the chute and into the quenching tank. Between 6 and 7 sec. is all that is required for the entire operation, including placing the valve in the jig.

How the Cell Works

The photo-electric cell is actuated by the frequency of the light waves emitted by the

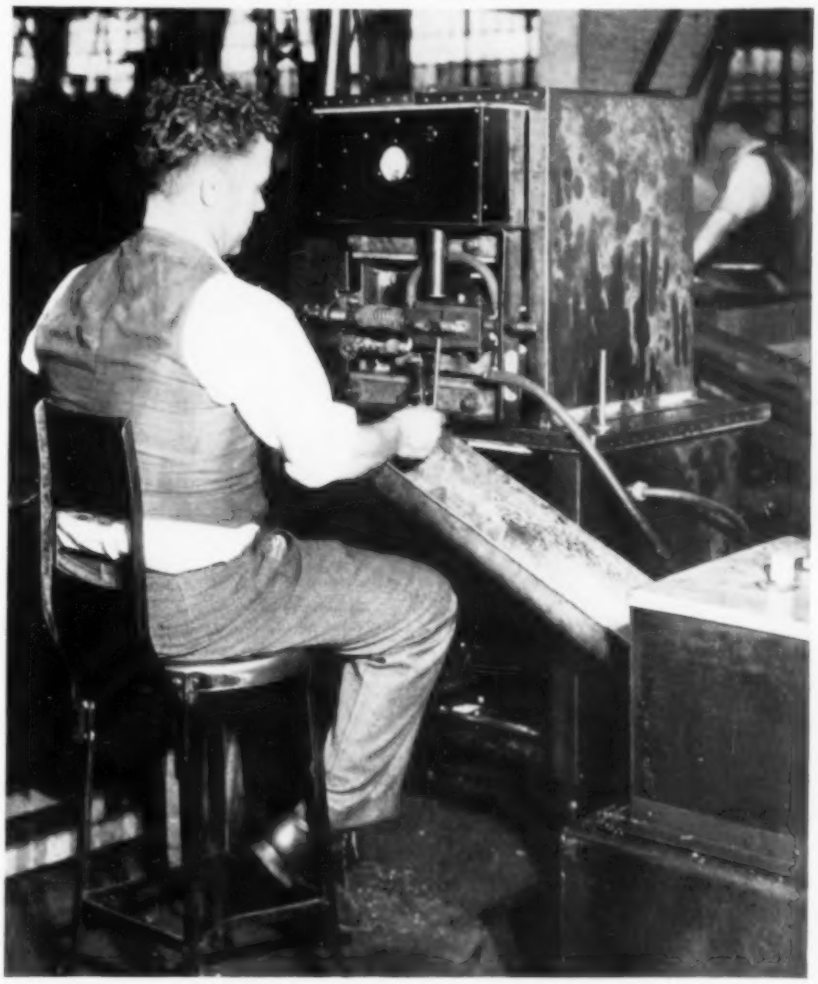
current used in a nine-hour day; greatly increased accuracy in temperature measurement (the photo-electric cell is accurate to within 15° of the desired temperature); and, consequently, more uniform hardening from piece to piece. Localized overheating is avoided by proper design and maintenance of electrode clamps.

As shown by the accompanying photographs, the device consists of copper electrodes which both grip and carry heat to the valve tip, a simple jig to hold the stem and valve in place during heating; a photo-electric cell, and the necessary electrical equipment including transformers, relays, batteries, and resistance coils. Multi-jaw electrodes are always in place on the machine so that undue wear (which would cause a sparking effect and pit the steel) can be



Hardness Zones Produced in Two Valve Steels by Electric Eye Device

Valve Tip Hardening Apparatus. Photo-electric cell is focussed on the work by a telescope



valve tip when at heat. As the temperature of the metal rises, its color changes cause an increase in the number of light waves emitted. When these strike the cell, electrons are released from the cathode and flow to the anode in a quantity which varies directly with the frequency of the light waves. This flow of electrons forms an electrical circuit, the current in which is so very small that it must be amplified by tubes similar to the amplifiers in a radio before it can actuate the first relay mentioned above. When this amplified current reaches a predetermined magnitude, the relay is opened and the main line heating current is cut off by the action of the second relay mechanism.

To set the device so that it will quench the valve tips from just above their critical range, it is therefore necessary to make adjustments in terms of milliamperes rather than in degrees. Manipulating a knob on the control panel is all that is necessary.

Two analyses of steels are regularly used by Thompson Products Co. for automobile valves. Silcrome steel, containing 9.5% chromium, 3% silicon, and 0.45% carbon, is used for exhaust valves. Intake valves are forged from S.A.E. 3140 steel containing 1% nickel, 0.60% chromium, and 0.40% carbon. Both steels are air-hardening but for convenience in handling they are quenched in oil after being hardened on this machine. Quenching temperatures are 1950° F. and 1550° F. respectively.

The drawing on the opposite page shows a typical cross-section of the tip end of the valve after hardening and indicates the relative position of the electrodes. The hardened area is cup-shaped and extends about half way down into the tip. Exhaust valves of the silcrome steel show an average hardness between Rockwell C-53 and C-54 after hardening. S.A.E. 3140 steel, used for intakes, hardens to about C-51 or C-52.

Hardness decreases, of course, toward the narrow band of transitional steel between the hardened tip and the annealed valve stem. In this range the silcrome valves show 46 or 47 on the Rockwell, while those of S.A.E. 3140 usually are recorded around C-43.

The stem remains soft despite its air-hardening tendency because of the very short time at heat and because the stem is long enough to be a rapid conductor. A reading of C-28 is obtained on almost every silcrome valve stem, with C-25 as the usual reading of S.A.E. 3140 valves.

Distortion is never experienced, nor is overheating, because of the close temperature control. So localized is the heating that discoloration is confined to the tip.

ALLOYS USED IN MACHINE TOOLS..

By D. M. Gurney
Metallurgist
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WHEN studying the history of man, we find that tools have played a highly important part in his development. In brief, man has been described as a tool-making animal, for without tools he is nothing, but with tools he is all. In the broad meaning, "tools" includes all the diverse ramifications of hand tools, utensils, machinery, and power-driven tools.

To bring this paper within measurable limits it will concern itself with power-driven, semi-automatic, and completely automatic machine tools. A "machine tool" is a device, manually or power operated, for the fashioning of parts by cutting, shaping, bending, or the removal of material. As a further limitation, I will discuss only those machine tools that are used in working metals, including such tools as lathes, planers, shapers, milling machines, drills, and grinders.

History of machine tools in the United States goes back approximately 100 years, although most of the important developments have taken place since the Civil War — in fact, since 1880. Materials entering into the construction of the earlier lathes, shapers, and drills consisted of a bed or frame of cast iron, a medium carbon steel for the moving parts or those more highly stressed, wrought iron for levers, bolts, and screws, and usually a high carbon tool steel for parts to be hardened to resist wear. Some cyanide hardening was done by bringing the heated parts in contact with powdered cyanide to produce a superficial hardness. A few of the older plants had learned the art of carburizing with solid carbonaceous materials, but others, due to lack of equipment and knowledge, for years depended on tool steel for hardened parts. Bearings consisted of either babbitt or bronze. A turret lathe of this decade is shown in the lowest illustration on pages 48-49.

Evolution in machine tool design and construction has been the result of a tug of war between the producers of cutting tools, of the materials to be cut, and of the machine tools. At first, the user had a few simple alloys to cut, namely, the ordinary carbon steels, wrought iron, cast iron, and the brasses and bronzes. To cut them he used quenched and tempered carbon tool steels, which could not cut at a high

rate of speed without overheating the edge and drawing the temper. Fairly light machine tools were therefore strong enough to withstand the stresses placed on them for such moderate duty. Soon after the beginning of the last half-century of progress, the Mushet or self-hardening tool steels were being introduced into the more progressive shops. These could be operated at faster speeds and deeper cuts, and therefore put heavier requirements on the machine tools. Still later, high speed steels were discovered and by 1910 were sufficiently well known almost completely to revolutionize machine tool design, increasing the weight and strength to withstand the heavy stresses put on them when the new tools were used to their full capacity.

For a considerable time during the earlier years of the automotive development, the changes in machine tool design were chiefly along the lines of perfecting the machines already existing. As the demand for greater production developed, the machines were made somewhat heavier and more accurate, with greater power and increased range. This trend is shown in the second illustration overleaf.

Design and Materials Changed

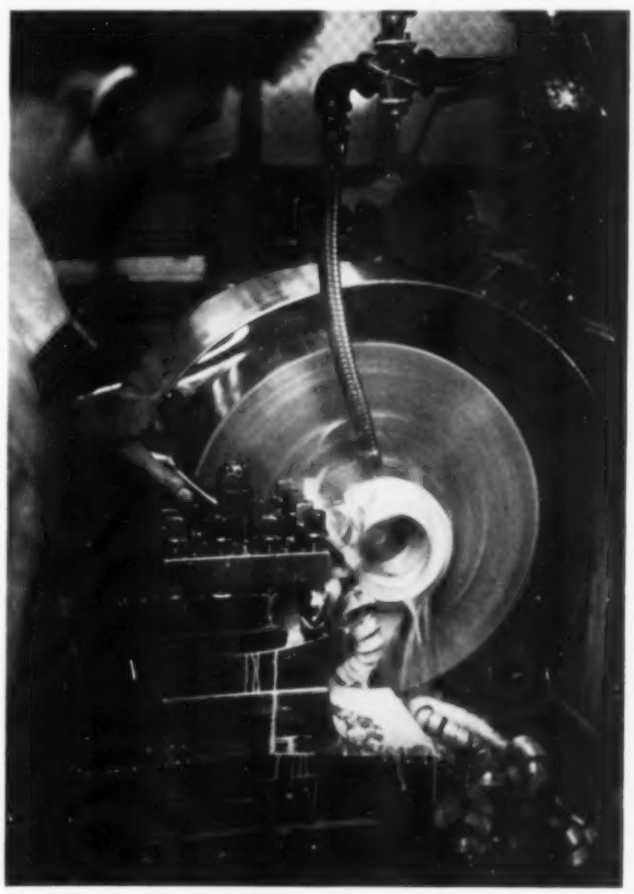
As inferred above, the development of high speed steel and the advent of the electric motor for driving were the two factors which largely affected the change in design and change in materials of construction of machine tools. High speed steel allowed greater cutting capacity and the electric drive provided the greater power for driving. Gear trains replaced screeching belts for reversing mechanism. These, combined with the ever-increasing demands for more and more motor cars at a lower price, were the outstanding factors in the increased size, speed, and capacity of machine tools. At first, cast iron gears were used in the driving mechanism; later, untreated steel gears were installed. Finally, case hardened carbon steel gears were required by the all-geared head, shown in the third illustration on pages 48 and 49.

Then came the advent of stellite tools with still further increased cutting capacities, thus increasing still further stresses on the machine. Even during the past three years the development of tungsten carbide cutting tools, and more recently tantalum carbide, has led to the belief that a revolution in machine tool design would result. However, it now appears that the necessary changes will be simply another evolution.

While this struggle between cutting tool and machine has been going on, the developments in materials of construction have been proceeding steadily. Higher and higher alloyed, heat treated steels are being machined; their hardness and toughness have been constantly increased, thus putting greater stress on both the cutting and machine tools. The ideal toward which production engineers are working seems to be a steel which can be completely heat treated in the rough, and a machine tool which can finish the surface of this hardened and toughened alloy at a high rate of speed and without damage to the part, to the cutter, or to the machine tool.

In order to realize these demands, it has been necessary for machine tool builders to adapt

High Cutting Speeds Are Made Possible by the Design and Materials of a Modern Lathe



these higher strength alloy steels to their own production before their machines could stand up to the stress of high speed production without being unnecessarily heavy and clumsy. It may fairly be said that manufacturers of machine tools have kept pace with the cutting tool development, and at present, the use of motor-driven, all-geared head with chromium-nickel steel gears and alloy steel shafts is the average rather than the occasional. In fact, the 16-ft. machine shown in the top illustration, representative of today's practice, and weighing 22,000 lb., is largely constructed of heat treated, alloyed metal. It has two distinct types of gray cast iron, a malleable iron, six grades of plain carbon steel, six or eight alloy steels (not including those in the roller and ball bearings), two brasses, four bronzes, copper, aluminum, lead, and babbitt.

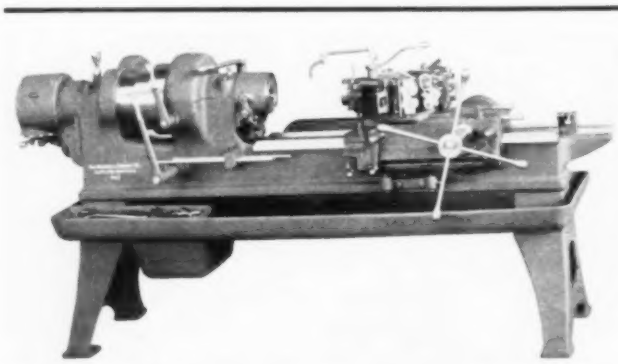
A survey of the industry in the Middle West, which includes manufacturers of radial drills, shapers, lathes, planers, and milling machines, shows the use of large quantities of $3\frac{1}{2}\%$ nickel steels of the carburizing and medium carbon types, low chromium-nickel steels, and medium chromium-nickel steels for gears, high duty shafts, and many carburized parts, such as clutches, spline shafts, pinions, sleeves, and studs. As a result of this survey, I believe that the engineering practice of most machine tool builders incorporates heat treated alloy steels to such an extent that the practice of one builder represents rather largely the practice of others. Machine tools in themselves are quite similar, although they may do dissimilar operations; nevertheless, the production or stress demands of one are not unlike those of the other. Therefore, to bring this discussion down to a specific study, I will discuss the materials going into the production of a turret lathe, since this is the product most familiar to me.

It is natural that the tool builder will borrow much information from the automotive industry, his best and his most rapidly moving customer. Consequently, alloys in general use are most of them defined by the Society of Automotive Engineers specifications.

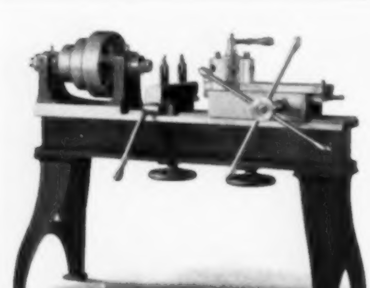
With few exceptions, all alloy steels are heat treated before use, the proper heat treatment developing in them the best combination of physical properties they are capable of possessing. In respect to the effects of heat treatment, each steel must be considered by itself.

Developments in alloy steels and in the heat treatment of steel have occurred simultaneously during the past 30 years, and care is needed lest the benefits gained from one be confused with those afforded by the other. The highest merit is obtained from the correlation of both developments, that is, the use of a uniform alloy steel heat

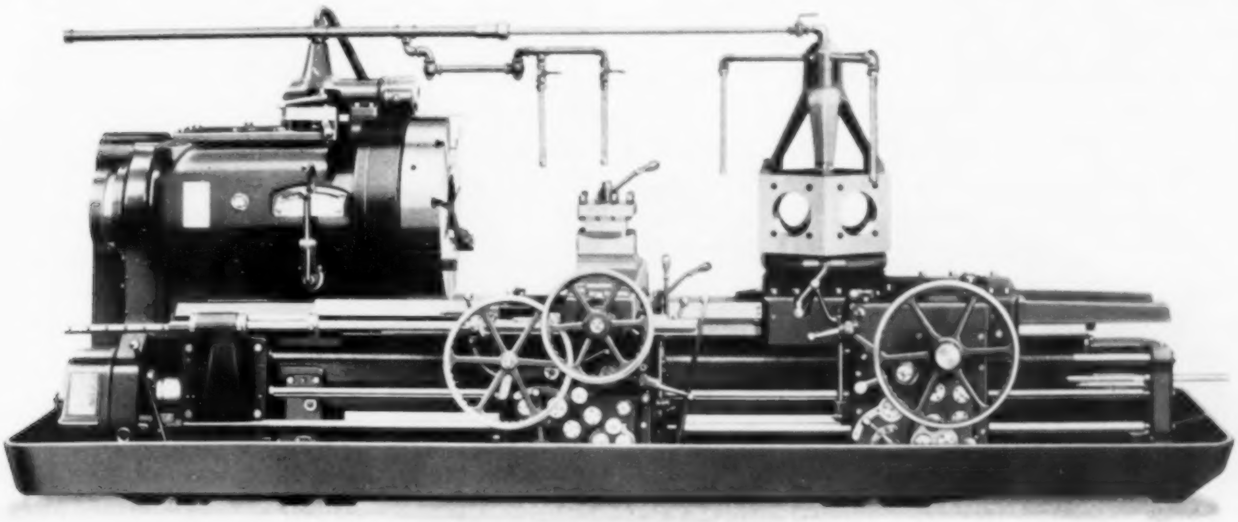
Individual Electr Motors and Complet ly Enclosed Ge Boxes for Spee Changes and Rapi Reverse Characteriz the Lathes Whi Were Built in 191 But even then, carb steel gears we standard equipme Note how rapidly th over-all size of lath increases with yea

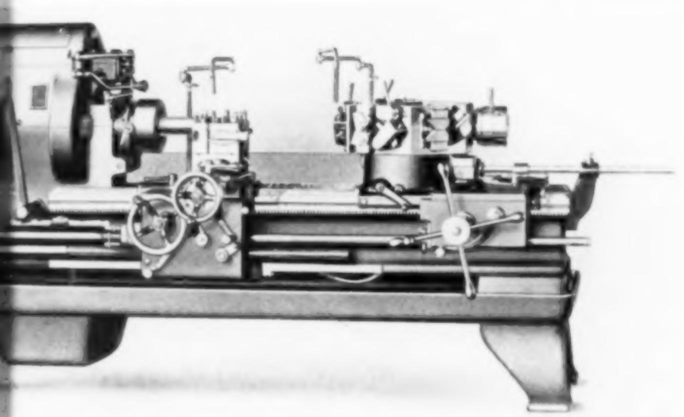


By 1900 the Machine Had Been Strengthened Throughout for Heavier Duty, and the Hollow Hexagon Turret Introduced, but the Machine Was Still Driven From a Jack Shaft, and Cone Pulleys Used for Speed Changes



An Early 16-In. Monitor Lathe, Manufactured by Warner & Swasey in 1881. All photographs on these two pages are on a scale of 3/8 in. to 1 ft.





More Speed and Power and Greater Work Capacity Are the Order Today, Exemplified by this 22,000-Lb. Lathe With a 36-In. Swing, 12-In. Spindle Capacity, and a 16-Ft. Pan

treated in a distinctive manner. Often the heat treatment contributes more to the superior properties of the final metal than does the use of alloys. In fact, a properly heat treated, medium-priced, carbon steel may be far more satisfactory than a poorly heat treated, high-priced alloy.

On the other hand, the demands by engineers for hitherto unknown qualities in the materials which they use, such as a greater resistance to abrasion, to severe shocks, strains, and stresses, and resistance to corrosion, have brought about the use of various alloying elements which, when added in proper proportion, will produce alloys which usually have physical characteristics far above those possible in the ordinary carbon steels.

Passing now to the consideration of definite metals and tool parts, we find that the 3½% nickel carburizing steel (containing 0.15% carbon, corresponding to S.A.E. specification 2315) has been extensively used for important parts of high grade tools by the machine tool industry for years. It has gradually displaced the simple carbon steels for parts requiring greater strength in the core and more uniform case hardness.

This steel is, without doubt, one of the oldest, best known, and most dependable carburizing steels on the market. The advantage of nickel as an alloying element has been expounded at length often, but from a production manager's or from a works metallurgist's standpoint its best points may be simply stated: The nickel alloys with the iron in the ferrite, increasing the strength and toughness by decreasing the grain size of this normally soft and plastic constituent. This iron-nickel solid solution has a lower critical range than the unalloyed iron, which permits carburizing and quenching from lower temperatures, and thus warping and distortion are minimized. Frequently, the grain size is so small in the core of a carburized piece that the high temperature quench for grain refinement may be omitted, a point especially valuable for parts that require very hard surface with minimum distortion. Consequently, intricate parts are made from this material, even

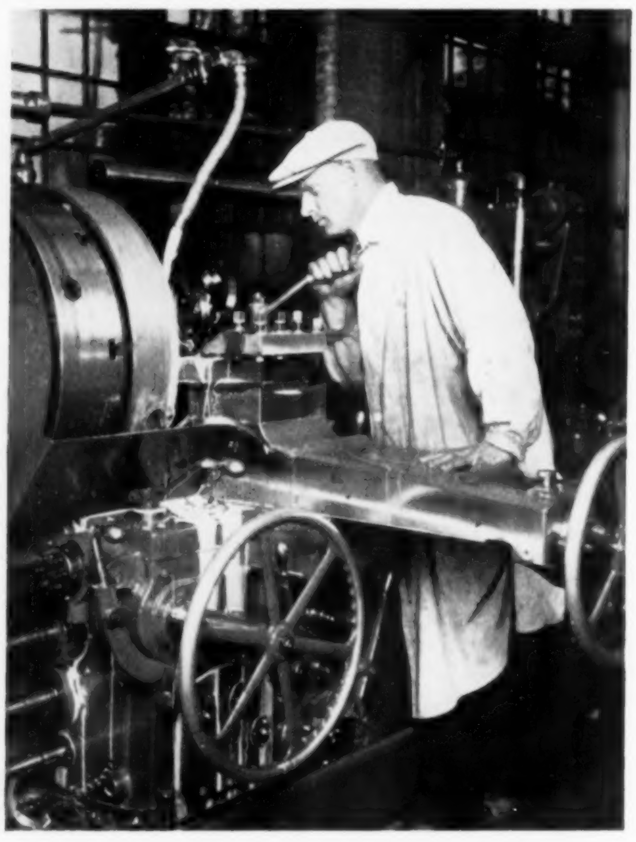
at an increase in cost or even when physical properties are not important. Sleeves, lock bolts, and lock bolt bushings are examples.

Higher carbon steels in this series of 3½% nickel steels are favored for the highly stressed shafts and gears by some manufacturers, but their use seems to be somewhat limited compared to the S.A.E. 3000 series noted below.

S.A.E. 2512 steel, containing 0.10 to 0.20% carbon and 5% nickel, has been called the ultimate carburizing steel by certain enthusiasts. However, it is not used in heavy tonnage by the machine tool industry, but finds greater use in the automotive field for parts of small cross-section where high hardness and toughness are required. This steel will produce approximately 40% better physical properties than S.A.E. 2315, and is used in place of the latter for such parts as gears and heavy duty clutches requiring the very best physical properties in the carburized condition.

Probably the most widely used alloy steels are those of the S.A.E. 3100 series, made in several carbon ranges from 0.15 to 0.50%, and containing 1.00 to 1.50% nickel and 0.45 to 0.75% chromium. The low carbon grades are used for carburizing purposes, the medium carbons for general forgings and structural parts, and the high carbons for oil-quenched gears. For a given carbon content, these steels do not develop quite as high physical properties as can the plain nickel steels.

Turning Down a 30-In. Bar of Hadfield's Cast Manganese Steel on a Modern Lathe, Using Carbide Tool



When carburized and double quenched, the 3100 steels show excellent toughness with slightly higher hardness in the case than do the 3½% nickel steels. When a single quench is given to harden the case only, the grain refinement and toughness in the core are not as good as may be obtained underneath the surface of carburized 3½% nickel steels.

In the range from 0.30 to 0.35% carbon, these steels find many applications for highly stressed bolts, screws, shafts, and rods that must possess high torsional values.

The 0.45 to 0.50% carbon grades are used mostly for gears; the high side of the range is designed especially for gears where great hardness is desired.

Steels with a somewhat higher amount of chromium and nickel (the S.A.E. 3200 series) are used in a rather small tonnage in comparison with the 3100 series mentioned above. The 0.40% carbon range, however, furnishes high duty shafts for heavy machine tools, while the 0.50% carbon steel is used for highly stressed pinions, gears, and where a steel of the 3100 series with an equal carbon content does not answer the requirements.

Molybdenum steels conforming to S.A.E. 4140 specification will be found in parts that are to be machined after heat treatment, because chromium-molybdenum steels of this sort possess exceptional machining qualities at high hardness. It is not uncommon to machine this grade of steel at Brinell values ranging from 321 to 418. This steel is therefore used for intricate parts, such as cross-slide screws and racks, requiring fair hardness and high physical properties that would be difficult to obtain without undue distortion in some of the other steels heat treated subsequent to machining.

In our enthusiasm over the development of ferrous alloys, we are quite apt to overlook the

important role being played by the non-ferrous alloys, such as the newly developed bronzes, alloys to resist corrosion, alloys of high tensile strength and high Brinell values. Fatigue-resisting alloys, others resisting shock, vibration, abrasion, and erosion — in fact, almost any copper, zinc, or aluminum alloy is obtainable for a large number of engineering purposes.

Machine tool builders have learned the wisdom of buying metals on guaranteed physical characteristics rather than on such open characterizations as "phosphor bronze" or "manganese bronze," and of considering the ultimate saving rather than the first cost per pound. Information about the manufacture, properties, and uses of these alloys is not as widely disseminated, or rather "absorbed," as are the data on steels; consequently, the engineering staffs of the producers are freely consulted for advice in specific requirements. Makers of these high grade alloys have carried out a vast amount of research in order to give the consumer an alloy best for his specific purpose.

Heat treatments have been perfected on certain types of bronzes, whereby the hardness is more than doubled. Bearing manufacturers especially have made careful studies of the crystal arrangement of various alloys in respect to their value as a bearing constituent, the hardness value of the micro-crystals having been definitely determined in order to perfect a more efficient bearing. They have also contributed valuable information as to the proper methods of installing bearings, proper machining methods, along with proper lubricating methods which we have found indispensable aids for designing equipment for long life and high efficiency.

Certain non-ferrous alloys are common to various machine tools. Among them is an aluminum bronze conforming to A.S.T.M. specification B-59-28, Grade B, and containing 89% copper, 10% aluminum, and 1% iron. This is a hard bronze with high physical properties designed to resist shock, and possesses the highest fatigue value of any of the commonly used non-ferrous alloys. Strength and hardness can be substantially improved by suitable heat treatment. It makes excellent worm gears and special feed nuts.

For similar parts where service is less severe, a bronze conforming to S.A.E. No. 62 is used, containing 88% copper, 10% tin, 2% zinc.

A high lead bearing bronze (copper 68%, lead 30%, tin 2%) has replaced babbitt bearings in numerous places. For other types of bearings, where a harder metal is required, a phosphor bronze conforming to S.A.E. No. 64 is used. It contains 80% copper, 10% tin, and 10% lead.

For miscellaneous soft yellow brass castings where cheapness and good machining qualities are the main considerations, S.A.E. No. 41 (copper 65%, lead 4%, zinc 30%) is usually specified. Castings requiring a high grade red brass with good machining qualities and high finish, where physical properties are not important, can be made from S.A.E. No. 40 (copper 85%, tin 5%, lead 5%, zinc 5%).

Alloyed Cast Iron

While our attention has been directed toward the betterment of steels and the non-ferrous alloys, the humble cast iron has been pulled from the shelf, dusted off, and, with a change in diet, has taken a new lease on life. This new diet (prescribed in the form of either nickel, chromium, or molybdenum, depending upon the diagnosis) has brought about most encouraging developments in the quality of gray iron castings.

Some years ago a prominent manufacturer remarked that the foundries were all fifty years behind the times, but were all up to date, as they were all alike! This statement was evidently made to accentuate the prevalent backward condition, and probably was not strictly true then, as it certainly is not now. One thing is certain — that the demands put forth today by industry for castings of higher quality have brought about better methods of control and closer cooperation between the manufacturers and users, with most salutary results for the quality and reputation of this invaluable engineering material. This is a matter, however, beyond the scope of the present article; I am glad to state that despite the use of advanced alloys and heat treatments, both for steels and non-ferrous compositions, the machine tool builder welcomes the advent of harder, tougher, more wear resistant, stronger, cast iron.

The Bolt Machine

Photo by Rittase at Reading Railroad Shops

. . . E D I T O R I A L . . .

A Year's Progress

1931, IN RETROSPECT, appears to be chiefly a year of personal and business anxiety. So many plans for betterment or for study have been postponed it would almost appear that the progress to be recorded is the tapering effects of things started in more prosperous and hopeful times.

Metal has been smelted or refined at such a low proportion of capacity that improvements by mass production have been impossible. Operators have rather given attention to the smaller furnaces and more flexible mills for turning out a small order quickly. Some noteworthy advances have been made in our knowledge of steel making, such as the production of ordnance steel at Watertown Arsenal with ferrozirconium instead of ferromanganese, and the manufacture at Pittsburgh of big heats of clean steel with silicomanganese doing the bulk of the deoxidizing. Such methods of conserving manganese will be of great importance in any future emergency when our imports of that necessary metal are restricted.

Engineers are giving increasing attention to the forge shop — that department which, to the casual observer, seems to be most wasteful of heat, metal, and labor. Studies on the effect of "reducing" atmospheres have proven that too large an amount of unburned fuel is necessary to prevent scaling or even to reduce it materially. Improvements in methods of combustion and in recovery of the waste heat offer better chances of economy. Great possibilities lie in the heating of billets in a muffle containing a controlled atmosphere; it will minimize scaling and grain growth, and under certain circumstances may eliminate some subsequent heat treatment.

Excessive costs of dies for drop forgings made by the hundred thousand have caused the introduction of coining operations in the tool room — master "types" are pressed into hot blocks, making a correctly shaped die needing only surface hardening before mounting in the hammer. Competition from accurately made die castings and the desire to avoid as much machining as possible are responsible for the production and installation of more rigid and precise hammers, presses, and forging machines for both hot and cold metal.

In the heat treatment department may be noted a consistent improvement in equipment — better designed furnaces, perfected heating elements, more accurate temperature control. As to methods, the idea of heat treating under controlled atmosphere is spreading rapidly. This includes not only gas carburizing and nitriding (some alloyed malleable castings appear to be hardenable by ammonia) but also the heating of steel tools in a non-scaling atmosphere and the bright annealing of strip, wire, and other semi-manufactured parts whose ratio of surface to mass is high. Whereas this last-mentioned scheme had formerly been regarded as applicable only to articles of high value, to high carbon steels which must not be decarburized on the surface, or to electrical sheet which had to be deoxidized to the limit, at least two large groups of bell-type furnaces for annealing the "tonnage" grades of sheet and strip have been installed recently. Operators usually find that the furnaces with controlled atmosphere have unexpected collateral advantages — that is to say, they not only perform the expected heat treatment efficiently, but also save money in the subsequent manipulation of the metal.

Other noteworthy observations are the use of differential heat treatment and the machining of fully heat treated parts. Differential

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heat treatment includes such things as the hardening of only those parts of a shaft or spindle, for instance, as rub on the bearings, leaving the rest in the toughened condition. The second advance mentioned has come about because tungsten and tantalum carbide cutting tools are able to negotiate metal of a Brinell hardness that would quickly ruin high speed steel. Frequently, the cost of heat treating in the rough and then finishing the harder metal is less than the usual routine of machining the soft steel, heat treating, straightening, and finally cleaning up or grinding to the required limits.

A notable achievement of the welders is the completion and publication of an extensive investigation of hand-made joints in structural steel, whereby it has been proven beyond question that tested welders working under procedure control in dozens of different fabricating shops can turn out work which is commercially uniform by test. Recommended design stresses have also been given a rational basis by this great series of tests. All in all, the result is a mass of data indispensable to the designing engineer, and everyone now agrees that welding will not come into its own until it is properly engineered.

A further impetus for rapid commercial development of welded construction has been given by the adoption of permissive rules by the Boiler Code Committee of the American Society of Mechanical Engineers and the various regulatory bodies which follow the lead of that committee. Many manufacturing organizations have also acquired the necessary information so they can now produce sound, ductile welds in thick plate by either arc or gas processes, and, better still, can prove to an outsider that they have done so. Constant advances in the speed of sound welding and labor saving devices are placing the welded joint in a better competitive position with other joining methods.

In the field of theoretical metallurgy one discerns a growing interest in pure metals. It is apparent that the commercial grades are contaminated by a number of elements in minute amounts, which frequently have a disproportionate effect on the physical properties. Alloys of pure metal, one in another, afford a continual series of surprises. The state of aggregation is also receiving more attention in studies of the behavior of large single crystals and the condition of the metal at the surface of sheet and wire. In the latter, X-rays are proving a powerful weapon.

Competition between materials goes on apace, despite the deflation which has struck all constructional materials. Such new things as cast iron camshafts, cast steel crankshafts, and engineered die castings merely emphasize the present state of flux which requires the close attention of someone in every manufacturing plant making any pretense of keeping ahead of the times or even abreast of its competitors.

Consider the Tool Hardener

EVERYONE knows that tool steel was about the only kind of metal heat treated in the average plant 25 years ago. Even today, when a hundred machine parts of plain and alloy steel are treated for every cutting tool, most hardening rooms have a pair of small furnaces reserved for high speed. Frequently, this equipment is a relic of earlier days, and would certainly tax the skill of the most expert hardener to make a tool in it which would possess the potentialities existing in the steel bar from which it was made.

Probably the reason why this tool hardening equipment has not long since been replaced is that it is called upon to do a very small amount of work. When tonnage has to be handled efficiently, the most modern furnaces are none too good; when equipment puts in a day's work a week, almost any make-shift serves the purpose.

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If the metallurgist or superintendent would stop to analyze this end of his job, or have the cost department do some figuring, he would most often discover that whenever it will not pay to modernize the high speed furnaces it will be cheaper to have someone else who *is* properly equipped harden all the tools. He will find that the most of the high speed steel entering his plant is in the form of finished tools, such as drills, taps, reamers, broaches, milling cutters. If he purchases tool bits for turning and planing, it may turn out that 90% of the tools in

active service have, in fact, been heat treated by someone else. Only in the very large and busy manufacturing organizations will the remaining 10% warrant the steady operation of special furnaces by a qualified workman.

The difficulty of properly heat treating a cutting tool does not reside in an intricate operation nor a precise temperature control. It is a mistake to assume, for instance, that a bevel gear presents an easier problem. The facts are these: When a plant hardens its own bevel gears, there are enough of them coming through at regular intervals so a desirable steel can be selected, a correct program or time-temperature cycle can be studied and adopted, and proper fixtures and other equipment — even furnaces — built for the job. The metallurgist makes sure that the raw steel is right, that his equipment is in adjustment, and that his instructions are obeyed; then the product will be as nearly perfect as the program is nearly correct.

Tools can be handled in the same way, and are so handled by a tool manufacturer. But things are different in the average shop. There will be one big one and 20 little ones; six others will be straight and the next one curved; most of them have an ample surplus for grinding; a few must be held strictly to size. In a single day's work the hardener may get standard high speed, cobalt high speed, non-shrinking steel, and plain carbon tools. And likely as not, the one requiring the most deliberate care is marked "Rush All Possible."

It is obvious that only a workman of great intelligence and skill can be expected to get a decent batting average in such a game as that. Some of his hits will be good, others not so good — yet tools are things where the best is none too good.

A logical and direct conclusion from this is that unless an experienced workman can be employed steadily enough to keep his hand in and his eye right, and to warrant providing him with good equipment under close control, the tools he hardens will fall far short of the uniformity and cutting ability that are demanded as a matter of course of drills or taps bought from outside manufacturers.

An alternative and preferable plan is to send such odd lots to a tool manufacturer (if such is within easy reach) or to a commercial heat treating plant, where enough of these specialties accumulate to make them a routine job. Sometimes a slight delay will be involved; sometimes the cost may seem a bit high; but either delay or cost is far less than would result from the failure of a tool improperly made, at home, at a fraction of its expected life.

Excuse It Please!

BY such a combination of errors as occurs now and then, even in an editorial office, proper and generous credit was not given for December's cover. The photograph was taken in Hollywood last Christmas eve, and shows a few of the hundred or more metal "trees" built about the lamp-posts along the Boulevard. Each tree had 96 electric lights in five colors; half of them, on blinkers, produced a shimmering effect which unfortunately cannot be conveyed in a still picture. Alternate strips of bright and dark metal lent a striking appearance even in the daytime. The trees were designed and patented by Otto K. Olesen, and built by the electrical illumination company which bears his name.

"HOT WELDING"

FOR SPEED . . .

AND QUALITY . .

By Gilbert E. Doan
Assoc. Prof. of Physical Metallurgy
Lehigh University

ELECTRIC arc welding is performed by drawing an arc between a metal wire and the steel parts to be joined. Thus an electrical discharge takes place between the wire and the joint, and this arc is similar, basically, to spark and glow discharges. Negative charges or "electrons" leave the cathode (the wire, usually) and impinge on the anode (the weld, usually), while positive charges or "ions" pass in the opposite direction.

The heat developed may be computed by the product of the amperes flowing times the arc voltage times the electrical equivalent of heat. (A small addition of heat is supplied by burning iron vapor.) Most of the heat is developed, however, not in the arc itself but at the two terminals of the arc — the wire and the joint — by the bombardment of incoming electrons and ions. These are exactly the points at which the heat is wanted.

Under ordinary working conditions, 200 amp. and 20 volts might be used, thus giving a rate of heat supply equivalent to about 5 hp. This large quantity of energy is concentrated on an area of less than 0.5 sq.in., and rapidly melts metal at both terminals of the arc. A globule forms at the tip of the electrode wire, and under the action of gravitation (in ordinary horizontal or flat welding) finally overcomes its adhesion due to surface tension and drops from the wire. It is not carried across the arc by the electric current.

The mechanism by which the globules form and detach is important. The action of this mechanism is improved by certain coatings on the electrode, notably such as sodium titanate, which produces a more rapid, uniform, and placid mode of globule detachment in addition to a steadier arc.

In the weld at the opposite terminal of the arc, and in the same short length of time, the intense heat has melted a crater or pocket in the closely abutted edges of the joint. If the operation is properly conducted, this crater is constantly lined with a thin film of liquid metal which flows rapidly toward the rear of the crater. Into this crater fall several globules per second from the electrode wire. They im-

mediately spread out and become a part of the flowing, liquid film and are swept along to the rear of the crater, where they solidify.

As the arc is slowly advanced along the joint, the crater moves with it, retaining its size by melting constantly at the forward end and solidifying at the rear end. In this manner, a succession of overlapping craters is formed. Behind the arc the successive films of metal at the rear edge of each crater freeze, forming the weld. These facts are the basis for the sketch on this page.

The rate of melting is high, due to the intense heat, and the rate of cooling is high also, due to the rapid conduction of heat by the cold metal surrounding the crater. The effect from a metallurgical standpoint is similar to casting superheated steel into a heavy chill mold with a molten lining, the "pouring" taking place as a stream of globules.

Effect of Surrounding Atmosphere

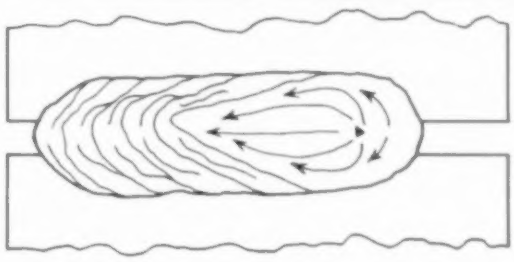
Since the melting and casting operation is carried on in an atmosphere of hot air, a rapid reaction between hot metal and oxygen and nitrogen must be expected. This reaction is stimulated by the following conditions: The liquid metal is superheated above its melting point; it is in a finely divided form with a large surface phase present; it passes through the arc (highly reactive, ionized air) a distance of about $\frac{3}{16}$ in. from the electrode to weld; and even after it has arrived in the crater, the metal is spread out as a thin film, and is there exposed to severe air drafts and scorification. Although the time of exposure of each unit of metal is short, the rate of reaction is very rapid and the weld metal becomes contaminated and quite unlike the original filler wire and plate.

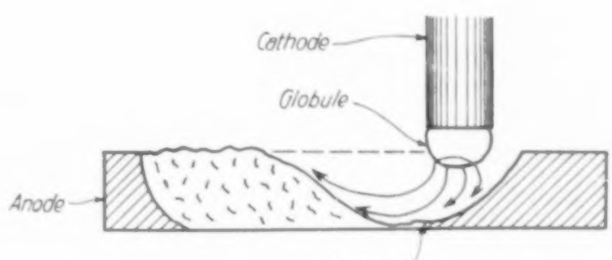
The rapid reactions taking place between the exposed molten metal and the atmosphere under these conditions are similar in nature to those in the open-hearth furnace when melting steel — that is, they are oxidizing. A considerable amount of carbon, manganese, and silicon, and sometimes even sulphur, is removed from combination, and the remaining iron contains much oxide. Some of the products of reaction are gases while others are solids. In addition to removing the above elements, oxygen and nitrogen are themselves absorbed rapidly by the metal during this exposure; these atmospheric gases are probably in an exceptionally active state due to their ionized condition.

Some of the solid oxides and the silicates formed in the reactions are entrapped in the weld metal. Due to the flow of heat from the weld, the iron solidifies very rapidly, and slag particles do not have time enough to coalesce and float to the surface. Some of the gases, also, such as carbon monoxide, remain entrapped mechanically when the metal cools, resulting in porosity.

As a result of these factors, the microscope shows that metal in arc welds deposited by hand or machine from bare electrodes contains oxide and slag inclusions, nitride "needles," and gas cavities. Naturally, such metal is not of high quality. It will possess about 40,000 to 55,000 lb. per sq.in. tensile strength and 6 to 12% elongation in 2 in. Average values for workmen of proven ability working under procedure control will be about 50,000 lb. per sq.in. tensile strength (measured at the throat of the weld) and an elongation of about 8% in the 2 in. including the joint. This represents metal of acceptable tensile strength for mild steel

Showing How Globule Drops From Electrode and Is Swept by Electrical Forces to Rear of Crater





structures but quite insufficient in ductility for steam boilers or members absorbing impact stresses.

The Bureau of Standards pointed out early in the art (Technical Paper No. 179, 1920) that the low ductility of the weld metal was due, in part at least, to the excessive amount of cavities and non-metallic inclusions in the samples it tested. In the intervening years much progress has been made in educating workmen how to make cleaner, denser welds. However, the ductility did not correspondingly increase.

Recent investigations by Hensel and Larsen, reported in Metal Progress last September, have shown that reaction with the gases of the air also embrittles the continuous phase — the solid metal — in addition to producing mechanical dirtiness and porosity. This is a discovery of prime importance to the welding art.

Nitrogen or oxygen from the air seems to combine chemically with the iron and to be retained in it as a supersaturated solid solution of iron nitride or iron oxide in alpha iron. (It is not yet clear which element is responsible for the bad effects noted, although these authors attribute the hardening to nitrogen.) Upon standing at room temperature for a period of two or three days, the familiar aging phenomenon then takes place. Insoluble constituents gradually precipitate from this quenched solid solution, and cause a very considerable increase in hardness and brittleness and a loss of ductility.

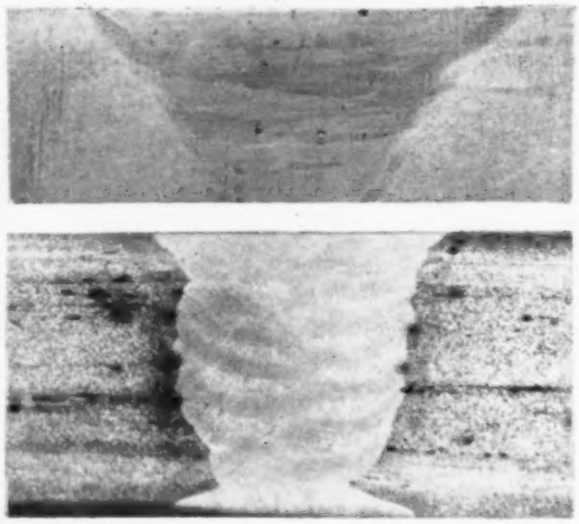
Arc welds are usually quite hard and strong in spite of the almost complete absence of carbon, the usual hardener in commercial iron alloys. Hensel and Larsen find that if the nitrogen content of the weld is above 0.05%, this embrittlement is quite marked. Although the aging embrittlement can be diminished, as in other aging alloys, by annealing the weld and causing a more complete precipitation and coagulation of the insoluble constituent, this step is frequently impracticable.

Reaction of the molten weld metal with air thus appears to be the cause of low ductility in the weld from at least two effects:

1. Mechanically entrapped slag and gas bubbles, and

2. Aging of the weld metal itself.

These conditions indicate that if methods



Etched Sections of Heavy Plate, About Half Size. Best quality of arc welds made from bare electrodes (above) contain many slag and gas pockets. Completely shielded arc (below) deposits a more homogeneous metal than the flange steel it connects

could be devised for preventing the attack of the ionized atmospheric gases on the hot weld metal, its ductility might be raised, possibly until it was equal to that of the steel parts being joined. How such attempts to exclude the atmosphere from the weld or to cleanse the molten steel were made, and how well they succeeded, is described below.

Excluding the Atmosphere

Metallurgists early recognized the opportunity to combat the attack of the oxygen of the atmosphere upon the weld casting by alloying with it those elements which, because of their affinity for oxygen, are commonly used as deoxidizers in the later stages of the steelmaking process. Less attention was paid to the nitrogen of the atmosphere. Aluminum, manganese, silicon, and also carbon were tried as deoxidizers. If these elements are present in the electrode in sufficient amount, they will enter the weld metal and may raise its tensile strength considerably, but its ductility seems to be only slightly improved.

Chromium, nickel, and other metals of this

group are also introduced into the electrode for the purpose of producing alloy steel welds. While these elements may have other desirable effects, they do not in general result in any considerable increase in ductility.

Another method of combating the attack of the atmospheric gases on the hot metal, and perhaps a more logical one, is to exclude from the beginning all access of oxygen and nitrogen to the arc. This takes a leaf out of the book of experience of oxy-acetylene welders. Other conditions being equal, a much more ductile weld can be made with bare filler rod melted by a blowpipe flame, for the burning gases effectively blanket the hot metal with a neutral or reducing atmosphere.

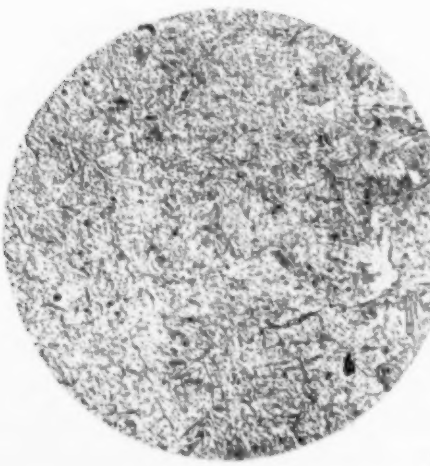
Some Wire Has Refractory Coating

One method by which this has been achieved in the arc process is to wrap the electrode in a refractory coating, such as the asbestos yarn used in making the Quasi-Arc electrodes. This wrapping melts more slowly than the wire inside it and thus forms a protecting crucible at the end of the electrode which partly encloses the electrode tip and the stream of globules coming from it, and offers some protection from the air. The coating also supplies a slag blanket around each globule and over the puddle in the crater. This method has been in use abroad for more than 15 years and yields a considerable increase in ductility of the weld, but it has never been generally adopted in this country, probably because in its early form it required a slightly slower rate of operation.

Another and more complete method of excluding air is to envelop the arc in a stream of neutral or reducing gas such as hydrogen, as is done in the "shielded arc" process of welding. This method does result in a weld of good ductility and is being used commercially. For the sake of simplicity, it would frequently be preferable to use the electric arc without the necessity of supplying it with gas.

Modern Coated Electrodes

Modern coated electrodes employ the blanketing principle outlined above. While the fundamental ideas are at present obscured by patent litigation and suits concerning the use of "secret" processes, it may be said that such electrode wires are covered with a $\frac{1}{32}$ to $\frac{1}{16}$-in. layer of cellulose, organic or mineral substances mixed with a suitable binder. This coating melts or burns more slowly than the electrode wire inside it, and soon forms a crucible about the electrode tip and extends part way to the weld. It is similar in this respect to the older Quasi-Arc coatings. Beyond the end of this crucible, however, the coating continues to protect the globules during their passage through the arc and down to the weld itself by supplying a reducing or an inactive envelope about the weld, thus excluding the reactive air to a great extent. Even the flowing



Microsections of Weld Metal at 100 Diameters. The photomicrograph at left represents a high quality joint made with a bare electrode; the one at the right shows equiaxed fine-grained metal at the center of a heavy joint made with a modern coated electrode

film of liquid metal down below in the crater itself is shielded.

Obviously, cellulose coatings produce this protective envelope by the combustion of the cellulose $(C_6H_{10}O_5)_x$. Success of mineral types of coatings is probably due to the circumstance that each individual globule of metal is enclosed in a thin envelope of molten flux which protects it, at least partly, from the air during its deposition. Down below in the crater, the flux blanket also covers and protects the flowing film of liquid metal.

Effectiveness of this blanketing action in protecting the weld metal during deposition can be measured by the amount of nitrogen or oxygen which it permits to enter the weld. Bureau of Standards found 0.0032 to 0.004% nitrogen in the bare electrodes before welding, and 0.111 to 0.156% in the weld after deposition, or 40 times as much in the weld as there had been in the wire. This amount of nitrogen was somewhat greater when higher welding currents were used.

Courtesy of Lincoln Electric Co.

With the modern coated electrodes, using much higher currents, the nitrogen content of the weld is less than 0.02%, or about one-seventh as much as the Bureau found for bare electrode welds. This low nitrogen content is said to be insufficient to cause aging embrittlement, and it permits a considerable rise in the ductility of the weld metal over that observed for the older practices.

There seems to be little doubt that this exclusion of atmospheric gases from the weld metal, which is accomplished by the coating on the electrode, has been responsible for the major increase in ductility of welds achieved by today's processes. That this coating was available and in use several years before its effects were understood (that is, before the discovery of aging embrittlement of welds by Hensel and Larsen) may seem strange, but practice is frequently far in advance of theory.

Hot Welding

Another factor in the attainment of ductility seems to be the extraordinarily increased rate of heating. Because of the intense heating the process has become known as "hot welding." Not only is the current two or three times higher than would be used with bare electrodes or with the Quasi-Arc type of covered electrode, but the arc voltage is higher also, thus further increasing the heat supplied. (Specifically, the 200 amp. and 20 volts of hand welding has been increased to as much as 750 amp. and 45 volts.) Furthermore, the heat is somewhat concentrated or caged in by the extending "crucible" formed at the end of the electrode.

The net effect of this intense heating of the weld seems to be that a larger volume of metal is molten at the joint at all times, and this greater amount of molten metal, lying under a layer of molten slag, solidifies more

slowly and has more opportunity to rid itself of gas and slag inclusions. Non-metallic inclusions, lighter in density than the metal, and, if possible, fluxed to a low melting point and viscosity, have more chance to coalesce and rise to the slag at the surface, leaving the metal relatively clean and sound. Welds of this kind, when examined in the author's laboratory by means of gamma rays from radium, appeared almost completely sound.

The new welding process thus supplies a double defense against contamination of the weld metal — it shields the molten metal as completely as possible from the surrounding air, and it holds the weld in the liquid state long enough for some of its impurities to escape. Illustrations on page 59 indicate effectiveness.

Straight, Even Seam Possible

It might be expected that the longer arc length used in "hot welding" would spread the heat too thinly over the welding region to be effective, would spray globules outside of the weld, or would flicker and swerve from the welding line. The combined effect of the extending crucible and of the high current seems, however, to compensate for these tendencies. The walls of the coating confine and stabilize the growing globule, and a stable globule makes possible a stable arc. The very high current has in itself a steadying influence.

The longer arc used in this type of welding is steadier in another respect, due to the steadier electrical conditions in the welding circuit. With the ordinary short arc, each globule touches the weld before it detaches from the electrode tip, thereby bridging the arc gap by a metallic conductor and extinguishing it momentarily. These periods of short circuit are revealed by the oscillograph as peaks in the current wave and dips in the voltage wave almost to zero, and occur as often as 20 per sec. or oftener. They constitute complete interruptions of the arc, although it is instantly re-established after the globule has detached. In modern coated electrode welding, the arc length is so great that the globule leaves the electrode before it reaches the weld, and at no time does it bridge the arc. The current and voltage are, therefore, much steadier and appear on the oscillogram as practically straight lines. This steady electrical condition seems also to be a desirable one for welding.

Courtesy of Westinghouse Electric & Mfg. Co.

Hot welding, in addition to the important blanketing effect, thus utilizes a steady arc which is intensely hot, and which results in a larger volume of liquid metal in the crater. The longer duration of the liquid state facilitates the escape of entrapped gases and of slag particles from the weld metal, and leaves it relatively clean and sound, and free from enough of those slightly soluble constituents which cause aging embrittlement.

These are results of very great value.

TEMPERED WIRE

strength varies with size

By R. C. Jordan
Wickwire Spencer Steel Co.
New York City

OIL-TEMPERED spring wire is high carbon wire to which the proper qualities (hardness, stiffness, ductility) have been imparted by a final heat treatment before coiling into springs. The commercial terms "oil-tempered" or "tempered," as applied to wire, represent a spring steel which has been hardened by quenching in oil from above the critical temperature and then drawn in molten lead, the three operations being arranged end-to-end in a continuous process. Some of the equipment is shown in the accompanying illustrations.

Chemical analysis of steel well suited for tempering will fall within the range:

Carbon	0.55 to 0.70%
Manganese	0.40 to 1.00%
Sulphur	0.04% max.
Phosphorus	0.04% max.
Silicon	0.10 to 0.20%

Carbon and manganese are generally on the high side of the limits noted above in the larger wire, and the low side corresponds to the finer sizes of wire.

In most steel specifications and in engineering design the tensile strength of a given grade of steel following a certain heat treatment is considered to be approximately constant regardless of the size of the section tested. The standard test specimen, for instance, is 0.505 in. diameter and is used no matter whether the piece is 1 in. or 10 in. through. If tests are made on material of a smaller cross-section the tensile strength, elongation, and reduction of area derived from test specimens of reduced dimensions might be compared to those obtained on a standard test.

As should be well known, the tensile strength of wire with uniform toughness or ductility varies inversely with its diameter, being high for small sizes and lower for large sizes. Oil-tempered wire is treated to develop certain uniform qualities of toughness, tensile strength, reduction of area, and Rockwell hardness, these properties indicating the ability of the wire to make the required severe bends without fracture. In limiting the extreme sizes to which this condition is true, $\frac{9}{16}$ in. may be used as a maximum and 0.030 in. as a minimum. (Springs made from wire over $\frac{9}{16}$ in. diameter are usually coiled before hardening or coiled from heated bars, while extremely small springs are usually made from music wire or from hard drawn spring wire.)

The tensile strength of steel made from the above analysis will vary as shown by the top curve on the data sheet, page 65, which was

outlined after reference to several hundred thousand tests of various sizes of such wire. An empirical formula

$$T = \frac{138{,}000}{\sqrt[4]{d}} - \frac{1{,}600}{d}$$

has been developed to correspond to the test figures, and the curve as shown is also a graph of this formula. Wire tempered to the strength shown should have a reduction of area at the tensile break of 40 to 50% and a Rockwell hardness between 38-C and 43-C. The latter figure varies considerably with the method of making the hardness test on round sections of varying diameters and surface hardnesses.

A tensile test and a severe bend test are usually sufficient to indicate the toughness of round oil-tempered wire. Unless the method of taking the Rockwell hardness is clearly described, it may well be left out of the specification. The true elastic limit and the limit of proportionality, which are very close together on a stress-strain curve of tempered wire, should be between 75 and 80% of the ultimate tensile strength. Within the practical range of hardness and ductility the elastic limit bears this fixed relationship to tensile strength, regardless of size or degree of hardness.

While the curve shows the minimum tensile strength to be expected in so-called "standard" oil-tempered spring wire, the figures may be varied within a range of 25% over or under for a given size by changes in the analysis of the steel and degree of temper. The change from low to high tensile wire is accompanied by an increase in hardness and a decrease in ductility.

Hard drawn spring wire usually has a somewhat lower tensile strength, size for size, as well as a considerably lower elastic limit.

Other special wires in small sizes, such as music wire and rope wire, may be made with higher tensile strength than oil-tempered wire. Music spring wire usually has a tensile strength about 30% above oil-tempered wire, but the elastic limit is less than for tempered wire of the same size. On the other hand, the working elastic limit of music wire may be increased to a much greater degree than tempered wire, by the method as mentioned below of winding the spring with too great pitch and compressing until the correct length is obtained by settage.

Hardened and tempered wires of the various sizes from 0.030 to 0.500 in. diameter show such a marked variation in tensile strength largely because the rapidity of the quench to the center of the cross-sectional area varies with the size and consequently changes the microstructure.

Entering End of a Continuous Oil-Hardening and Tempering Equipment Used to Treat Spring Wire

Influence on Spring Design

These figures for strength and the question of what stress to use are important to those designing and using springs. Since the properties of the wire change with size, it is reasonable that the spring made from a fine wire with a rather high tensile strength is relatively as good a design as a spring made from large wire with a much lower tensile strength, other things being equal. The stress in a helical spring may be considered to be simple torsion for the purpose of approximate design, while the stress discussed above is tension.

Since tempered wire has a practically uniform structure, whether taken on a cross-section or longitudinally, we may assume that

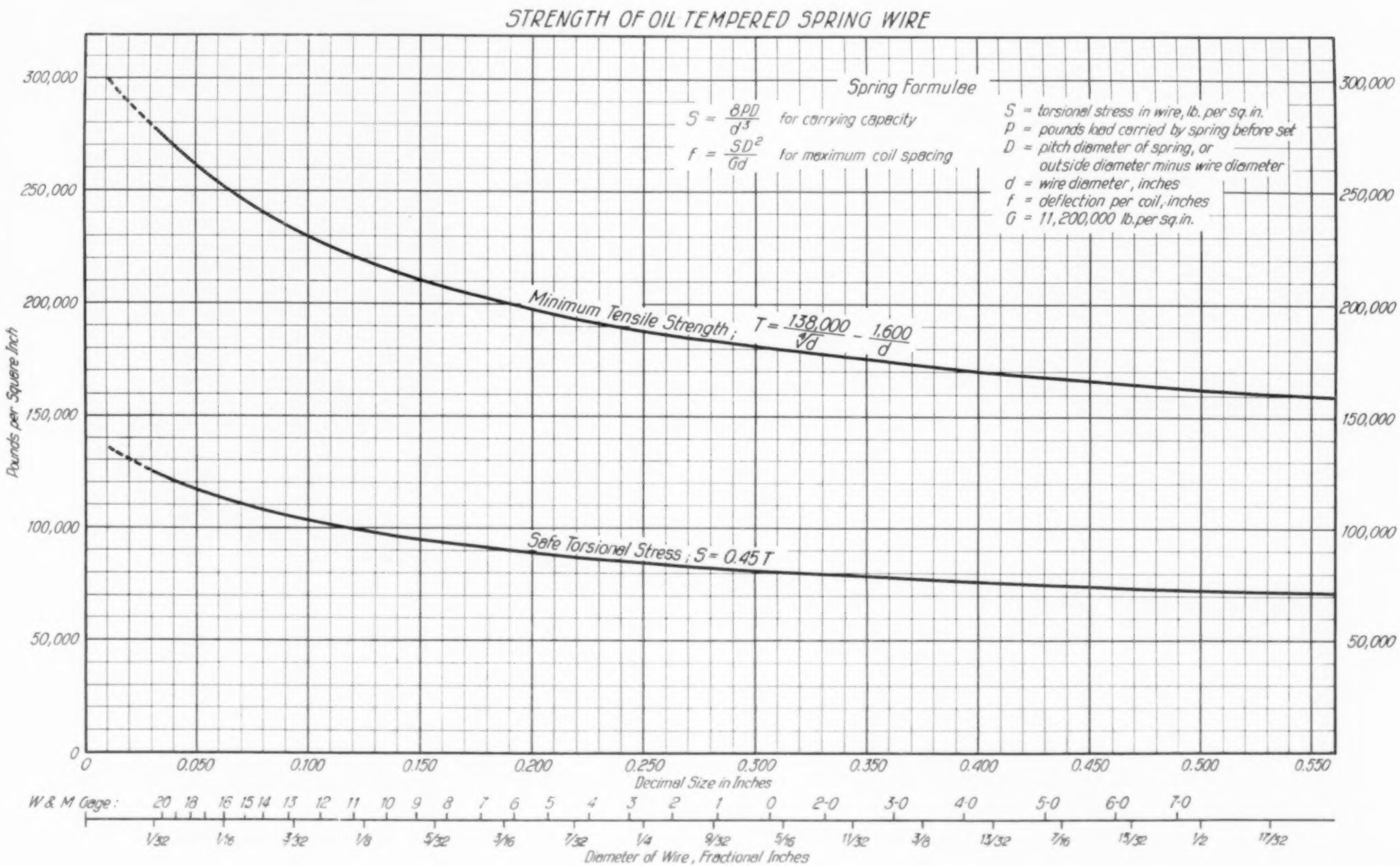
the torsional breaking stress and torsional elastic limit are proportional to the ultimate strength in tension. For instance, a series of tests on springs made from tempered wire showed that settage occurred at a torsional stress slightly less than 45% of the tensile strength of the steel. Assuming that the term T in the strength formula opposite represents the minimum tensile strength, and knowing that the actual value will fall within the probable manufacturing range of 10% over that figure, the designer may use a torsional stress of 45% of the value T as calculated from the diameter, or taken from the curve, and be reasonably sure that springs wound on pitch from standard wire will not "set" — that is, decrease in length after compression until the adjacent coils touch. With harder wire a higher stress may be used, but care must be taken not to use stiff wire when the design requires abrupt bends or when the spring is to be used for high fatigue duty.

Simplified spring formulas are given in the data sheet because in commercial practice the exact but more cumbersome formula including the pitch angle between coils is frequently neglected for approximate computations.

Cold Work Increases Strength

Safe working stresses somewhat in excess of these figures may be obtained from high tensile oil-tempered wire by winding a spring with too great pitch and then "setting" by compressing solid, so that upon release the pitch is correct. This, in effect, increases the true elastic limit by the cold work of deformation after the spring is coiled. Higher stresses may also be used for music spring wire, as outlined above. In most problems of this sort the engineer or designer would do well to consult with the specialists on the staff of the wire or spring company from which he intends to procure the material. Springs and spring wire comprise a subject about which too little is known by the average consumer.

The Photograph Above Shows the Wire Entering the Oil Quench After Having Passed Through the Hardening Furnace. At the right is a photograph of the lead drawing bath, showing the 6-ft. take-up blocks for continuous oil tempering of wire in diameters as large as 9/16 in.



Data from R. C. Jordan, Wickwire Spencer Steel Co.

CORRESPONDENCE . .

. . AND FOREIGN LETTERS

Slightly Decarburized Surface Lowers Endurance Markedly

LONDON, ENGLAND — A good deal of attention has been given in recent years by American investigators to the surface decarburization of steel during the heating processes to which it is subjected during manufacture. Special interest has been added to this question by the publication of a paper by two British authors, Dr. Hankins and Dr. Becker, of the National Physical Laboratory. This paper relates to the effect of surface decarburization on the fatigue properties of typical spring steels such as are used for the best types of automobile chassis, but attention is confined entirely to the surface changes which occur during hardening and tempering, the surface decarburized during rolling having been intentionally machined off.

This mode of attacking the problem, which may appear peculiar at first sight, arises from the way in which the question developed in the earlier researches of the Springs Research Committee, in the course of which it had been found first that a leaf spring, as rolled, could develop not much more than one-third of the safe range of fatigue stresses as compared with a ground and polished test piece cut from the same plate. It was then found that by removing the surface layer of the plate a much closer approach to the endurance of the test piece could be achieved while, on the other hand, a test piece which was hardened and tempered, however carefully, became seriously deteriorated in regard to resistance to fatigue after being machined to size.

Hankins and Becker, continuing these investigations, have now obtained good evidence for the conclusion that the deterioration which occurs during heat treatment is due to surface decarburization. This leaves the piece with a soft and weak skin which fails under a low fatigue stress, with the result that the surface cracks are propagated into the body of the steel and lead to fracture.

These conclusions might have met with a somewhat sceptical reception had not the authors gone further and shown that by carrying out the heat treatment under conditions which avoid decarburization — that is, under slightly carburizing conditions — the deterioration is also avoided. With this confirmation of their views, however, the ideas of Hankins and Becker are receiving a good deal of immediate practical attention from those concerned in the production of springs of all kinds. Since the whole difference between the commonest steel and the best special spring steel is easily effaced by these surface effects, it is clear that the maker and especially the user of springs has very much to gain by the avoidance of the defective surface layer.

Fortunately, the remedies proposed and tried by the investigators are simple and practical — such as keeping the steel covered with powdered graphite during heating, or carrying out the whole process by means of salt baths containing a suitable concentration of cyanide. Therefore, efforts to apply these remedies on a manufacturing scale should not be difficult. At the same time, these remedies have so far only been tested as a means of avoiding the relatively slight (although still very injurious) decarburization which occurs during heat treatment, and the problem of avoiding decarburiza-

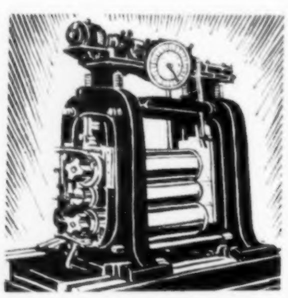
tion during the earlier and rougher stages of manufacture may prove to be more difficult to solve and to put into practice.

The decarburized layer which is produced in these earlier stages of manufacture as at present carried on is as a rule very much deeper, and the removal of carbon has usually gone much further than in the treated test pieces used by Hankins and Becker. Usually, too, there is a layer of oxide or scale on the surface, sometimes with little films of oxide penetrating into the intercrystalline boundaries of the steel close to the surface.

The exact state of the surface will, of course, depend upon the conditions in which the steel has been heated and it may prove well worth while, where high-grade alloy steels have to be heat treated carefully, to control the conditions in the heating furnace so as to minimize or to prevent decarburization. Whether, if carbon has once been removed, it can be subsequently replaced by some suitable mild carburizing process remains to be seen; it is a question of economic working as well as of metallurgical technique.

It is perhaps worth pointing out, in conclusion, that although this matter has arisen and has been studied in connection with spring steels, it has a much wider application.

Wherever steel parts are used without surface machining and are exposed to fatigue stresses — more especially where these stresses are of a bending or torsional nature, so that the maximum fiber stresses occur at the surface — there the presence of a weak decarburized surface layer becomes a source of danger and has to be met, in present practice, by the use of much heavier sections so as to reduce the range of active fatigue stresses to the limit which can be borne by the weak surface layer. This amounts actually to throwing away the entire advantage which is obtainable by the use of heat treated alloy steels.



It seems quite likely that the disappointment which has sometimes been expressed at the results given by heat treated alloy steels in practical service may be traced to the existence of these weak surface layers in one form or another. If we learn to overcome these defects we shall thus be helping forward the development of heat treated alloys by yet another step.

WALTER ROSENHAIN

Magnesium Alloys Consumed in Quantity in Italy

TURIN, ITALY — Since it is impossible in brief letters to describe all the interesting new apparatus shown at the Milan exhibition, I will confine myself to some points concerning the Italian industry. Outstanding is the great development of light metal castings, both aluminum and magnesium alloys.

One of the most interesting sections among those containing complete plants in operation was occupied by Società Forni Elettrici. This firm specializes in furnaces of the electric resistor type; it installed a complete aluminum foundry and kept it constantly in full operation. Visitors were given every opportunity of ascertaining the costs and other data concerning the production of the various castings (such as raw materials, labor, power consumption) and could personally compare these results with the ones achieved in their own foundries, and therefore grasp immediately the technical and economic advantages that might be expected by the purchase of the equipment exhibited.

It would take too long to quote the numerous metallurgical companies exhibiting the very interesting products of their light alloy foundries, but I cannot pass over the excellent exhibit of magnesium alloy castings made by Isotta Fraschini, well known as builders of automobiles and airplane engines. It has erected a large foundry especially for making castings of the alloy known under the commer-

cial name of "Elektron." Excellent results have also been achieved with another magnesium casting alloy known as "Maxium."

The new foundry, whose capacity far exceeds the needs of the Isotta Fraschini company, for which it was primarily erected, has easily found a market for its excess production among different Italian engineering works. Our industries are now rapidly adopting the extra light magnesium alloys for an increasing number of machine parts of every description, such as weaving machines, railway cars, street cars, and military equipment. I will probably have the opportunity later to enter into more details concerning some new and interesting applications of these alloys in Italy, but I have thought it proper to mention them here because this section of the Milan exhibition was the one giving the best example of the circumstances I have developed in my letter last month.

Another section of the exhibition, to which the same remarks apply, included molding sands and new, simple, and practical apparatus for testing them. Noteworthy was the iron foundry, exhibited in active operation by Bonvillain & Ronceray of Choisy-le-Roy, France, which had an array of remarkable automatic machines for sand dressing.

For many years past, Italian foundries have imported large tonnages of molding sands from France and Belgium. Deposits of excellent sands have been recently found in central Italy which can meet the most severe requirements for all kinds of steel castings. Various types of these sands could be subjected to the different physical tests by the visitors themselves in this section of the exhibition, where the best modern testing machines were placed freely at their disposal.

The field of electric steel manufacture showed many important new devices. Among the most interesting was the new regulator first designed for the Tagliaferri steel furnaces, which changes and regulates the speed of the electrode movement according to the quality and the physical condition of the charge in the furnace. Many of these very simple devices have been recently installed in Italian, English, French, and German steel works.

Finally, I cannot end this short report on the Milan exhibition without mentioning its historical section. Among many other interesting objects, it contained the first industrial electric steel furnaces built by Stassano in Darfo (Lombardy) and Turin, between 1900 and 1903, and regularly operated by him since that time on a commercial scale for the production of special steels of every description. In spite of what has been repeatedly said and written on many occasions (for instance, about the priority of the electric steel furnace put in operation by R. Lindenberg in February, 1906, in his works at Remscheid, Germany) these Stassano furnaces are certainly the first electric furnaces to make special steel commercially.

FEDERICO GIOLITTI

Soviet Copper Development Resembles Utah Enterprise

Moscow, U. S. S. R. — The largest developed copper deposit in the world is within ten miles of the Great Salt Lake in the State of Utah. Utah Copper Co.'s mine, which is the largest open pit copper mine, and the two concentration plants, one of which has a daily capacity of 35,000 tons of ore and is the largest in the world, are considered masterpieces of mining art.

As if by some strange freak of nature, there is another great salt lake, Lake Balkhash, situated at about the same geographical parallel, in the Kazak Republic of the Soviet Union. This lake is 65 miles long and 25 wide — practically equal in length to the Great Salt Lake, though only somewhat more than half the width. About 15 miles to the north of Lake Balkhash are the rich Kounrad copper deposits. The similarity extends even further — even the grade of the ore is similar to that found near your Great Salt Lake, the average copper content of the Utah ore being about 1% and that of Kounrad 1.2%.

The Kounrad copper deposits are estimated to contain 1,500,000 tons of copper metal and the concentrator now under construction there will have a daily capacity of 50,000 tons of ore. The total output of the Kounrad and the adjacent copper mines is expected to be about 1,000,000 lb. of copper daily, or half the present copper consumption of the entire U. S. S. R.

But the similarity between the localities of these two great salt lakes does not extend to either vegetation or climate. The country surrounding Lake Balkhash is entirely barren, resembling the central section of the State of Nevada, rather than the farming region surrounding Salt Lake City. The climate is also more rigorous, running to extremes — in winter the thickness of ice is often as much as seven feet, while in summer the heat is so great that eggs can be cooked in the hot sands!

There are virtually no roads in this desert, no navigable rivers and no inhabitants. Camels have been, and still are, the chief means of transportation. The nearest railroad center is Petropavlovsk on the Trans-Siberian railway, about 550 miles from the northern part of Lake Balkhash. To the south, measuring directly through the lake, it is about 100 miles to the nearest point on the recently constructed Turkestan-Siberian railway.

To connect this, the richest copper deposit in Soviet Russia, to the existing railroad network, the Soviet Government has decided on the construction of a railroad between the copper mines and Petropavlovsk. Already about 300 miles of this 550-mile branch line has been completed and opened for passengers and freight.

It is planned to finish the copper mine and concentration plant by 1933. The smelter plant is to have an annual output of 200,000 tons of copper. The total cost of the project, including railroad, is estimated at about $250,000,000. It will be equipped with the most up-to-date equipment, part of which is being ordered in the United States; the designs are the joint work of American and Soviet engineers.

The difficulties to be overcome are tremendous. In the endeavor to ship materials 2000 camels were employed, but half of them died of starvation. The task to be performed is not confined to the construction of the copper plant. A whole new city must be built in the middle of the desert country and all the auxiliary industries have to be developed.

However, all the natural assets for a vast industrial center are available. Recent geological expeditions have discovered considerable coal deposits, the extent of which makes this locality the third most important coal region in the Soviet Union. It is estimated that these deposits in the Karaganda district may contain up to 70 billion tons of coal. The Kazak Republic also possesses important resources of lead and zinc. Current estimates give this territory about two-thirds of the copper and lead and over half of the total zinc resources of the Soviet Union.

Thus, in the next few years the Russian salt lake district will be opened up for exploitation as Utah has been. It is indeed a miracle of nature that the earth's forces should have created two such centers at opposite sides of the earth, almost at the same geographical parallel, possessing practically the same types of natural wealth.

V. M. Karmashov

Several Grades and Uses of Bessemer Steel

Youngstown, Ohio — Recent attention by editors and writers to the subject of bessemer steel is warranted by the present position of the process. This first method to fulfill the demand for a better and more economical metal for constructional and commercial use still possesses definite advantages

not fully appreciated by the rising generation of engineers and designers.

To the outsider, its principal aspect is the spectacle of a great tongue of flame roaring from the mouth of the vessel, a glare visible at night for miles — obviously the result of the expenditure of huge amounts of energy. Indeed, few of the oldest workmen ever become insensible to this display of power and beauty.

However, bessemer steel is retained not for the spectacle, but for its utility. Most metal users know that brittleness from oxygen is remedied by the addition of manganese to the blown metal, and that brittleness from phosphorus must be regulated by selecting low phosphorus ores for making the pig iron destined for the converter. In the American acid practice, no phosphorus nor sulphur is eliminated during the blow; in fact, there is an increase of nearly one part in ten, due to the burning of nearly 10% of the weight of the charged metal (carbon plus silicon plus manganese plus iron).

Contrary to the opinion which seems to prevail among the trade, "bessemer" is not a one grade steel. It is made by the Republic Steel Corp., with which I am connected, in several grades and for a number of different purposes. To correct the false impression of a solitary bessemer grade, it would be well to note the following essential facts concerning it:

1. Most bessemer steel does not possess extreme ductility. However, a special grade is made for sheets which gives good ductility, and the use of this is increasing rapidly.

2. Bessemer steel is excellent for galvanized and tinned products where a certain amount of stiffness of the sheet is required in addition to good ductility.

3. One of its particular properties is that it can be bent or formed to shape and will retain this shape under repeated stresses, where steels made by other processes fail because of their lack of resilience.

4. Any grade of bessemer carbon steel can be made in acid converters except those of low phosphorus specification.

5. Bessemer screw stock, which is higher in sulphur and manganese than the soft grades of steel, is unexcelled in machining qualities and is the standard of comparison for all free cutting steels.

6. The welding properties of bessemer steel are among its most valuable but less widely known qualities. This is demonstrated in the making of butt-welded pipe where bessemer steel is almost without competition, and in numerous applications of hammer welding. It also gives excellent results in fusion welding — even in the higher sulphur grades where machining qualities must be considered.

L. B. Grindlay

Hereditary Influences on the Quality of Cast Iron

Paris, France — An account of the Milan Foundry Exhibition has been given by Dr. Giolitti in his letters to Metal Progress, which I would like to supplement by a brief glimpse at the technical problems discussed in the various communications read during the Congress.

An invitation broadcast by the executive committee resulted in 44 communications from the various European countries and America, most of which were read during the meetings. A glance at the titles enables us to classify them in the following way: 19 related to cast iron, 4 to aluminum, 2 to steel, 4 to alloys of copper and nickel, 4 more to the study of sand and other materials for molds, and 11 related to general subjects.

This classification shows that the intensive study of cast iron which began some 15 years ago is still continuing and indeed occupies a major part of the foundryman's attention.

An effort will now be made to summarize

the problems which are uppermost at the present and the prevailing ideas concerning them. Neglecting those subjects including the applications of metals and alloys, their chemical analysis, and also those dealing with some specialties, such as molds and manganese steel, particular mention should be made of the following:

1. Gas solubility, especially in molten aluminum, and the gas evolved from the metal before casting were discussed in communications by Pontremoli ("Colata di placche di laminazione") and by Barbero ("Sanità e resistenza dei pezzi fusi").

2. Influence of the casting temperature on properties was noted in the above-mentioned paper of Pontremoli and in those of Blasic ("Fisiche di un bronzo") and Gabino ("Colabilità dell'acciaio").

3. Control of the properties of the raw materials and the products manufactured therefrom. This is the principal object of communications by Viez and by Sulliotti and Capello on sand tests, by Balma and by Mei on the wear resistance of cast iron, by Ros and Eichinger ("Bruchgefahr des Gusseisens"), by Norbury ("Properties of malleable in various sized test bars"), by Portevin ("Les facteurs et défauts de fonderie"), and by Gabino, already mentioned above.

4. Organization of foundries and the classification of raw materials and foundry defects were considered in Castelain's, Monti's, Prever's, and Gierdziewski's communications.

5. Cast iron melted in the electric furnace was treated in communications from Dupuis and Braghieri and from Del Grosso.

6. Most striking is the number of studies treating of two problems relative to cast iron, (*a*) heredity and (*b*) oxidation. The following communications are directly or indirectly connected to these two problems:

Association Technique de Fonderie Belge ("L'oxydation envisagée comme facteur d'hérédité"), Thyssen and Buffet ("L'hérédité des fontes"), Boegehold and Joseph "(High silicon pig iron for malleable iron manufacture"), and Sirovich ("Influenza delle piccole aggiunte di alluminio alla ghisa grigia per getti").

Even though some of the last-mentioned papers cite some experimental facts and interesting practical observations, others contain many conjectures and opinions which are not supported by systematic studies and rigorously scientific tests. The debate which they provoked indicated a tendency on the part of foundrymen to assign an importance to those phenomena of heredity and oxidation which is not perhaps entirely free from commercial influences and the desire to disclaim responsibility. I shall have occasion to speak again on this subject. A. PORTEVIN

Flame Hardening of Rubbing Surfaces on Shafts and Gears

BRANDENBURG, GERMANY — After three years of experimentation Bergische Stahlindustrie, Remscheid, has perfected a double hardening process which is notable for its simplicity and efficiency. The company calls it "Doppel-Duro," but it may also be called, descriptively, "rotation hardening" or "flame hardening" depending upon which of these two characteristics of the method is judged to be the most important.

As I have already noted in a communication to *Automobiltechnische Zeitschrift*, October 10, 1931, it is especially applicable to round parts which need to be hardened only on those finished surfaces which rub in bearings, such as automobile crankshafts. A special steel has been developed for this purpose, known as BSF-Duro, which corresponds closely to your S.A.E. 4140 and contains 0.45% carbon, 0.5 to 0.6% manganese, 1.0% chromium, 0.25% molybdenum, and 0.25% silicon. It can attain through this process a scleroscope hardness of 80 to 90 Shore (600 to 700 Brinell). Other standard alloys and even medium carbon steels have been treated satisfactorily.

The method consists of heating a portion or band of the surface by a high temperature

flame, and traversing the flame over the surface by a slow but steady rotation, whereby the hot portion is immediately cooled so that a continuous hard surface results.

It should have been mentioned that a crankshaft would first be forged, normalized, machined, and then hardened from 1475° F. in oil and drawn at 1175. In such condition it would have a tensile strength of about 130,000 lb. per sq.in. and Brinell hardness of about 300, a toughened condition ready to receive a high surface hardening on the bearing surfaces only.

For this localized surface hardening an oxy-acetylene flame is utilized. A special blowpipe produces a wide, white, graduated tongue of flame 0.3 in. long and rounded on the end. The width of the flame used so far is from ¼ to ½ in. The latter is sufficient to harden a bearing surface ¾ in. long in one traverse, since the flame mushrooms slightly on impingement and since the hardened metal must merge gradually into the unhardened part, so that the elasticity of the edge will not suffer. For longer bearing surfaces, the smaller flame is utilized. It would then be mounted on a fixture which moves slowly sidewise as the shaft rotates, thus traversing it in a helical path.

The shaft is mounted in a lathe in such a manner that the axis of the part to be hardened is in line with the axis of head and tail stock. It is partly immersed in a tank of circulating cold water. The burner is placed about ⅛ in. from the steel and pointed so the flame impinges on the surface radially, and along an element of the bearing just above the water line. When this first strip is heated to about 1200° F. (as judged by color or optical instrument), slow rotation of the shaft starts, at such a rate that the approaching metal is heated to the correct quenching temperature immediately before being submerged in the quenching fluid.

When one rotation is completed, the surface of a short bearing is hardened. At the end of the process there is an overlap which produces a narrow softened strip. This area may be minimized by an auxiliary water jet; the soft area is also so placed as to be at that position on the crankshaft bearing where the surface pressures during operation are at a minimum. In longer bearings, where the small flame traverses the surface in a helix, the tempering effect of the flame passing nearby is minimized by a water jet which plays on the already hardened portion of the cylinder.

The hardness achieved is, of course, due to the rapid quenching of the metal from above the critical range (in this steel, about 1000° F.). There is no increase in the carbon at the surface, as in case hardening — only the surface layers are heated above the critical, and they are immediately quenched to martensite. Depth of hardening, as measured on a fresh fracture, is from 0.10 to 0.20 in., depending upon the relationship between size of flame, mass of shaft, and speed of rotation under the flame. (For small shafts the latter is about one per minute.) Transition between outer hard surface and inner core is gradual, as proven by hardness studies on cylinders hardened by this method and taper ground.

When all the bearing surfaces on a shaft are hardened as above, it is annealed for two hours in an oil bath or oven at about 340° F. to relieve strains. It is then tested for hardness and shape; cold straightening is done if the finish grinding will not correct the alignment.

Similar methods have recently been successfully applied to the teeth of gears made of carbon steels. Surface hardness of 45 scleroscope was attained on 0.25% carbon steel, and 60 scleroscope on 0.45% carbon steel gears. Some work was published in England several years ago indicating that this method causes extremely small dimensional changes in a properly prepared gear. In this respect the flame hardening process may be compared with the more recent nitriding process.

GUIDO PRACHTL, Dr. Eng.

DEEP NITRIDING

by program control

By J. W. Harsch
and J. Muller
Leeds & Northrup Co.
Philadelphia

OUR store of knowledge pertaining to nitriding and its operations is being augmented daily through the results of researches covering the many variable factors influencing the process. The factors are as follows:

(*a*) Materials in the reaction zone,

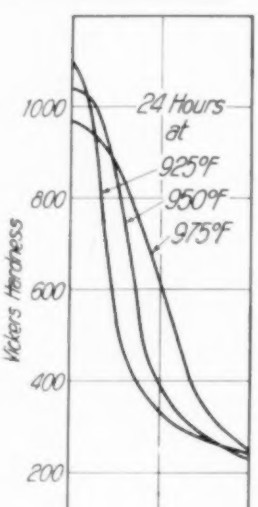
(*b*) Temperature at which the reaction is carried out,

(*c*) Time during which the reaction proceeds,

(*d*) Rate and manner of flow of the active chemical.

The process is not considered difficult if close control of the above variables is effected. Results obtained by properly controlling these variables show that one factor depends upon another.

Materials in the reaction zone other than the parts being hardened (principally the work container) were discussed in an article in METAL PROGRESS last month. We showed there that nichrome and low manganese monel metal are most suitable because they neither affect nor inhibit the nitriding reaction nor are they themselves disintegrated.



Moderate Changes in Nitriding Temperature Affect Surface Hardness and Penetration

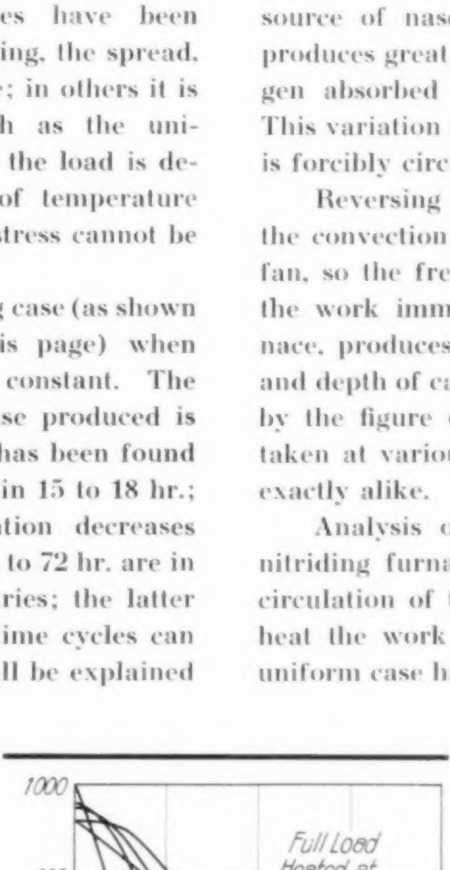
Temperature has a two-fold effect upon the resulting nitrided case: It governs the surface hardness and the hardness gradient within the case. The first figure (on this page) shows graphically that the maximum hardness of the case is some inverse function of the temperature of the reaction after nitriding at various temperatures for 24 hr. and keeping the temperature constant. The temperatures shown on the curves (925 to 975° F.) are those most commonly used in commercial nitriding. It is apparent that uniformity of heating inside

the container is important, for a 25° difference, piece to piece, will produce a noticeable variation in hardness and penetration in the cases.

The charge can be heated either by conduction or convection or both. A comparison of the temperatures existing in various regions in ordinary box-type heating, in non-reversed convection heating, and in reversed convection heating will show widely varied degrees of spread in temperatures during heating and after the control temperatures have been reached. In some types of heating, the spread, point to point, will be very wide; in others it is almost non-existent. Inasmuch as the uniformity of hardness throughout the load is dependent upon the uniformity of temperature throughout the load, too much stress cannot be placed upon the latter.

Time influences the resulting case (as shown in the diagram printed on this page) when temperature and flow are kept constant. The relation of time to depth of case produced is not a straight-line function. It has been found that most of the case is formed in 15 to 18 hr.; thereafter the rate of penetration decreases rapidly. Cycles ranging from 24 to 72 hr. are in daily use throughout the industries; the latter is the economical limit. Such time cycles can be considerably shortened, as will be explained later in this article.

Flow, or the rate at which fresh ammonia is introduced into the furnace, materially influences the surface hardness obtained on the work. The percentage of the ammonia which dissociates during the nitriding reaction varies with the rate of flow, with temperature of the work, and the area of heated reactive surface in contact with the gas. The effect of flow is more pronounced at the higher temperatures; on the other hand, it appears that there is a certain maximum rate of flow for any given temperature which will secure the maximum hardness and depth of case in the material which is to be nitrided.



Rate of Penetration Is Rapid During Early Stages of the Process and Then Slows Down

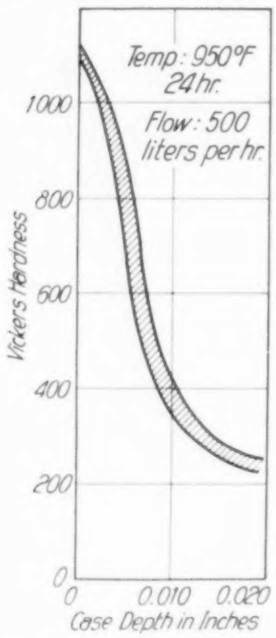
Distribution of available ammonia throughout the load is as important as a uniform temperature. Without forced gas circulation, the work nearest the incoming supply of ammonia will absorb more nitrogen than the farthest work. Concentration of the various constituents of the gas stream changes as the nitriding reaction proceeds and the gas soon becomes depleted of the essential ammonia which is the source of nascent nitrogen. A slow velocity produces great variation in the amount of nitrogen absorbed in different parts of the load. This variation is minimized when the active gas is forcibly circulated.

Reversing the inlet flow of ammonia into the convection furnace synchronously with the fan, so the fresh incoming gas passes through the work immediately upon entering the furnace, produces very uniform surface hardness and depth of case throughout the load, as shown by the figure on the following page. Samples taken at various places in the load are almost exactly alike.

Analysis of the sequence of events in a nitriding furnace reveals that reversed forced circulation of the treating gases is essential to heat the work uniformly and thus produce a uniform case hardness in every part of the load. A study of the absorption of nitrogen by the various parts of the load emphasizes the necessity for reversing both the circulation and the ammonia inlet, thereby bringing all the work into contact with a uniform atmosphere.

Program Control

Commercial nitriding cycles used today are normally designated by the time during which the work is at some constant nitriding temperature; that is, 24, 36, or 48-hr. cycles. The complete sequence of operations takes more time, and is as follows: (*a*) The properly heat treated, finished, and cleaned



Eleven Samples Were Taken Along the Axis and Three Along the Edge of a 312-Lb. Load, Nitrided in Convection Furnace. All hardness-depth curves fell within hatched band —very good uniformity

work is charged into the cold reaction chamber or container; (*b*) the chamber is sealed and flushed free of air with ammonia; (*c*) when the air is eliminated, the loaded chamber or container is heated to and (*d*) held at the nitriding temperature for a predetermined length of time; and (*e*) the reaction chamber and the work are cooled.

Hardness-depth curves shown for a constant temperature nitriding cycle indicate a change in hardness from a maximum at the surface of the steel to the hardness of the original core in a few thousandths of an inch. Such a case is made up of hard materials possessing little ductility, and for some classes of work it must be of sufficient depth and strength to withstand high unit bearing pressures.

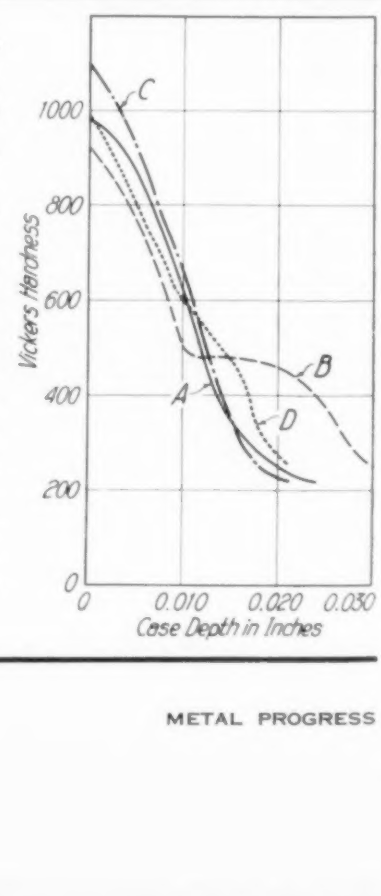
Service conditions to which gears and valves are subjected are particularly exacting, and require a core of high hardness and strength. The core hardnesses, however, are limited by the maximum hardnesses which can be readily machined (Brinell 250 to 280, approximately, for the usual alloys), and core materials of corresponding physical properties cannot withstand high bearing pressures without deformation. The low core strength and steep case gradation are necessarily compensated for by a deep nitrided case which requires considerable time to produce.

Attempts to shorten this time without sacrificing surface hardness have been successful where the nitriding operation is carried on at two widely separated temperatures for equal lengths of time (first at a low temperature, then at a higher). This process is generally called the "duplex" treatment. The hardness penetrates deeper, but there is an abrupt and undesirable change in gradation. This is shown on the last curve, in dashed line *B*, representing conditions found after a duplex cycle of 12 hr. at 975° F. followed by 12 hr. at 1190° F. For reference, a full curve, *A*, gives typical results from an equivalent time at steady heat (24 hr. at 975° F.).

High surface hardness and a slowly but uniformly decreasing hardness with depth of penetration are procured by the "program method of control," wherein the nitriding temperature is progressively changed from a low to a high temperature. It is based upon the rate of formation and of diffusion of the various nitrides produced at various temperatures in proper nitriding atmospheres. Automatic control may easily be handled by the temperature recording and controlling instruments.

Surface hardness, case gradation, and case depth may be changed by varying the rate of increase of the temperature during a nitriding cycle. If an extremely hard case is required, the work will be nitrided at one of the low nitriding temperatures for a definite period of time before progressively increasing the temperature. Rate of change should be small at the lower nitriding temperature (900 to 1000° F.) and large at the higher (1000 to 1160° F.). In other words, the work *(Continued on page 94)*

Penetration of Hardness According to Typical Methods of Temperature Control.
A after 24 hr. at 975° F.
B after 12 hr. at 975° F. followed by 12 hr. at 1190° F.
C after 5 hr. at 930° F. followed by slowly rising temperature, reaching 1150° F. in 19 hr.
D after 24 hr. slowly rising temperature from 900° to 1140° F.



CONCENTRATES

from current . .

literature . . .

ANNUAL reviews of technological progress in *Mechanical Engineering* are always inclusive and informative. Singled out for special mention in the December issue by the editors are the Hudson River bridge, the airship Akron, a welded gas-line from Texas to Chicago, a 1000° F. steam turbine, and carbide cutting tools — every one of which required notable contributions from the metallurgical industries before it could be accomplished. In the section devoted to progress in **aeronautics** the following items of metallurgical interest are included: Weight of naval aircraft has been reduced by use of stainless steel or aluminum alloy floats. Much study is being given to the relative merits of propellers made of forged aluminum alloys, magnesium alloys, and hollow steel. The trend in Army aircraft is toward monocoque metal fuselage and all-metal wings, with stainless steel for all external tie rods and parts subject to corrosion. In the engine department there has been a steady increase in power without increasing the weight of the power plant. Interesting features are exhaust valves with hollow stems, filled with copper or sodium, and improved bearings of lead-bronze, steel backed, which can safely carry the highest loads now developed in aircraft engines.

LABORATORY investigations and plant operation under precise control have produced an "unburned" magnesite brick, cheaper yet better than the burned brick, according to A. E. Fitzgerald, writing in *Mining and Metallurgy* for December. Of course, the original **magnesite** is calcined, as usual, driving off the CO_2. The dead-burned grains of well-crystallized periclase are then ground, screened, the graded sizes mixed in proper proportions for minimum voids, coated with a colloid binder, and pressed at 10,000 lb. per sq.in. — some ten times the conventional pressure. This produces directly a brick which is harder, stronger, denser, and of more stable size than a brick more lightly pressed without binder and burned a second time. Second burning causes nothing but recrystallization, shrinking, and bonding of the original periclase particles. Unburned brick have demonstrated their superiority in many applications, including linings for basic electric furnaces and other furnaces where the hearths or walls come in contact with hot iron oxide.

RESULTS of a four-year research by W. E. Jominy and D. W. Murphy, sponsored by the American Gas Association, into the heating of steel for **forging** are contained in Bulletin 21 of the Department of Engineering Research, University of Michigan. It is divided into three sections; the first discusses the nature of overheating and "burning" and finds that the plain carbon steels can be heated quite close to the burning point without damage. Next the question "How fast can a steel piece be heated without damage?" was investigated and answered: "Any practicable rate does no harm to billets up to 4 in. square." The last portion has to do with the formation of scale by the furnace gases, and the means whereby scaling may be minimized — some of this has been already presented in Metal Progress last September, where it appeared that the best way to avoid scaling in practice is to avoid excess air in the flame and to remove the steel from the furnace just as soon as it reaches forging heat. Other portions of the work are contained in *Transactions*, A.S.S.T., but the 150-page booklet

contains so many important facts that many users of forgings (and all manufacturers) certainly will find it a good investment at $1.

A PATENTED electrolytic process for making metal patterns is described by C. O. Herb in *Machinery* for December. A waterproofed wooden **pattern** is first made; this is placed on a flat surface and covered with plaster of paris. When this has set the pattern is removed and the mold oven-dried, waterproofed, and "made resistant to the solution of the electrolytic bath, except in the mold cavities." Here, evidently, is one of those "secret" processes which an enterprising experimenter could probably rediscover in a short time—also the unstated method whereby the plaster of paris is made a good conductor of electricity, for the next operation is to plate the cavity with copper up to 1/4 in. thick. The copper shell is then filled with a fusible alloy, some brass inserts set (for attaching the pattern to the plate), the back milled flat, the inserts drilled and fixed to the molding machine plate and the plaster cast broken away.

POINTING out that the most effective means of decreasing railroad operating expenses is to increase the capacity and reliability of the tractive power, a writer in *Railway Age* for November 21 says that a trend in **locomotive** design is to increase the effective horse power of the machine much faster than the weight is increased. Alloy steels have enabled the designer to do this, a notable instance being their use in boiler plate whereby the steam pressures may be increased without increasing the weight of the boiler. Another metallurgical change of importance is the adoption of one-piece bed castings which have removed many heavily stressed joints, each one requiring much maintenance. Special materials for bushings, packing rings, roller bearings, and special steels for pins which provide harder bearing surfaces also decrease maintenance charges on the prime movers.

VALVE seat troubles have multiplied in high speed, high compression engines, especially those that operate for long times at maximum speed, as in a cross-country truck or bus. Valves which give the effect of "pounding in" are in reality eroded at high temperatures. Aluminum bronze **valve seats** have proven unsatisfactory because their coefficient of expansion is higher than the cast iron block or head in which they are set, and consequently, they quickly loosen. According to *Bus Engineering* for December, the White Motor Co. has solved the problem by the use of a machine steel ring screwed and pinned tightly into a recess in the cylinder block. The ring has previously been covered on its inner surface with a layer of stellite welded on and rough ground to form. After assembly, final grinding is done with a high speed wheel to tolerances of about 0.001 in. This alloy has high strength at red heat, and it is expected that the removal of valve seat trouble will enable the engine manufacturer to take full advantage of balanced crankshafts, higher speeds, and higher rear axle ratios, thus saving weight in the engine.

SALT BATH heating, particularly where only a portion of the steel part is to be hardened, has seldom been mechanized. W. G. Park, (*Heat Treating and Forging* for November) describes briefly such a plan for rear wheel truck hubs. All equipment is located under the chain conveyor leading from the final machine operation. Special hangers carry the hubs through a gas-fired preheater and then into a **lead bath** 7½ ft. long, where the hub flange is immersed the exact depth. Reaching the far end, a quick transfer is made to a shallow oil bath, where 3/8 in. of the end is given a preliminary quench; another transfer lands the hot hub on a quenching fixture (caustic soda). The final operation is a hot water wash. Transfer from furnace to fixture is done by pairs of rotating arms, motor driven and controlled by limit switches tripped by the advancing conveyor links. Six heat treaters have been replaced by one machine tender, and the uniformity of the product improved to such an extent that the hub can now act as one of the races of the roller bearing.

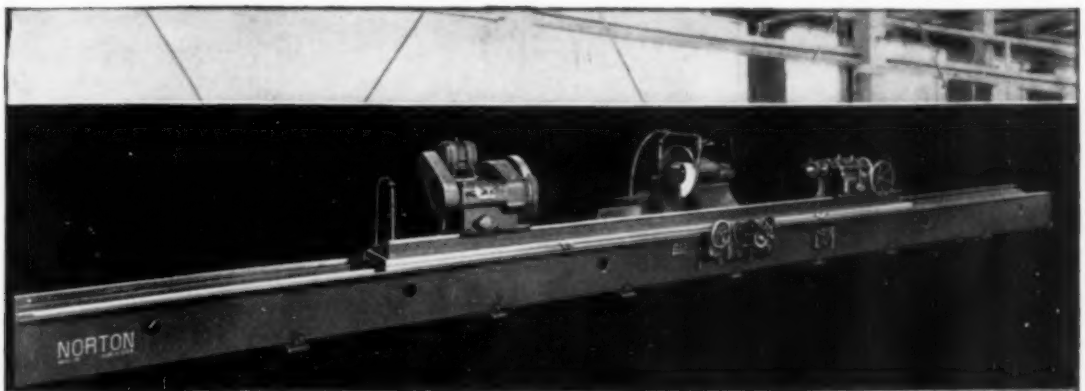
AN informative series of articles by Wm. J. Merten on the nitriding process has been running in *Fuels and Furnaces*. In the seventh and eighth chapters *(Continued on page 80)*

CONCENTRATES

(Cont. from page 78) (November and December) he recommends nickel plate plugs or caps to protect those regions of the surface which must be kept soft. A plate up to 0.0005 in. thick should be deposited from a high density hot solution using high amperage and pure anodes. **Denitriding** (softening the nitrided case of the aluminum steels to a machinable extent) can be done in a fused 50:50 mixture of potassium chloride and common salt. These pieces can later be rehardened. A chemical reaction probably takes place between the iron nitride at the steel surface and the salt at about 1500° F., forming the gas NCl_3; diffusion outward of more nitrides from deeper layers effectively softens the surface. It follows that nitrided surfaces cannot remain hard in any hot atmosphere containing chlorine; this accounts for the pitted condition of gas engine valves when the fuel contains ethyl chloride anti-knock.

A SECOND edition of Stuart Plumley's "Oxy-Acetylene Welding and Cutting" has been issued (University Printing Co., Minneapolis). Originally, the book was a series of 20 lessons covering nearly all phases of **gas welding**. It has now been doubled in size and contains supplementary chapters on boiler codes, regulations, and laws, on hard alloy overlays, and on welding of high carbon steel tools (saws, principally). It is primarily a text book, and as such will be most useful to teachers and workmen, but since it is encyclopaedic and remarkably well illustrated, it may be consulted frequently with advantage by supervisors, inspectors and designers.

NEW welding equipment exhibited at the Leipzig fair is described in *Engineering Progress* for December. A curious statement is that the "Arcatom" process (a German term for the well-known atomic hydrogen process) was "originated by Griesogen m.b.H." Another of this firm's "important innovations" is the so-called Arcogen process, wherein the welder operates an oxy-acetylene *(Cont. on page 82)*



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In This 57-Foot Norton Cylindrical Grinding Machine

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CONCENTRATES

(*Continued from page 80*) blowpipe in the right hand and a metallic arc in the left. It is claimed that twice the speed of the gas process is thus achieved with no deterioration in quality of the joint. An interesting development is a line of light weight torches made principally of aluminum alloys. The recurrent claim of a cutting blowpipe which does not alter the surface cut also reappears in this article.

A SPECIAL questionnaire on the use of cemented tungsten carbide tools was returned by 85 manufacturers to a research committee of the American Society of Mechanical Engineers and summarized at the convention held in New York early in December. Three reports on the properties and performance of **carbide tools**, tool steel tools, and stellite tools were also read. The first mentioned contained detailed data on 21 operations on lathes, automatics, boring mills, milling machines, and drill presses wherein large savings resulted from the substitution of carbide tools for ordinary high speed, cobalt high speed, and stellite. Most of the jobs were cast iron, bronze, and aluminum alloys. It was emphasized in discussion that the proper, if not the only way, to make an accurate comparison of the three varieties of tools is to select a foreman interested in the highest possible production, and have him set aside three machines working on a given piece, each tooled properly with the respective material, and guide each operation so the combination of speeds and feeds for lower cost per piece can be found by trial.

ACCORDING to Messrs. Blum, Barrows, and Brenner (Bureau of Standards Research Paper No. 368), porosity in **chromium plate** may be determined by depositing copper on it from acidified sulphate solution at 0.2 volts, across a gap of 2 in. Cracks and pores are covered with the copper, and a measure of the porosity is the current passing per unit of cathode area. It was generally found that thin chromium plates (up to 0.00002 in.) contain fine holes, and the number of them does not increase with age. Thicker deposits (up to 0.0001 in.) have parallel cracks in the direction in which the base metal was last polished, or alligator skin markings — both varieties of which increase in extent with age. It was found that chromium plates made in tanks operating at or below 113° F. show a marked minimum in porosity when about 0.00002 in. thick. Deposits produced at higher temperatures, say up to 150° F., have lower porosity and this does not markedly increase as the thickness of the plate increases. At any given temperature the porosity decreases with decreasing current density, but full advantage cannot be taken of this, for current density and temperature must be coordinated to obtain bright plate. Porosity is least when chromium is plated over nickel, and greatest on steel (when the work is done according to present commercial practices). These results may have only a general relationship to corrosion resistance, as baking a fresh deposit will increase porosity.

Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin D-22.

Aluminum Welding—Aluminum Company of America. Instruction card to be hung in the shop for ready reference, giving directions for welding aluminum. Bulletin D-54.

Hacksaw-Ology—Simonds Saw and Steel Co. Book illustrating and describing the uses of hacksaws. Bulletin D-69.

Industrial Application of the X-Ray—General Electric X-Ray Corp. Booklet gives many examples of the use of the X-Ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin D-6.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Modern Industrial Furnaces—Surface Combustion Corp. Booklet covering the research, development and engineering activities of the Surface Combustion Corp., and their application and the advantages obtained by S-C furnace users as a result of these factors. Bulletin N-51.

Atmosphere Controlled Gas Furnaces—American Electric Furnace Co. has just issued a new four page bulletin showing sizes, capacities, and description of the Juthe gas furnace with controlled atmosphere in the chamber. Bulletin JA-2.

Conveyor Belt Handbook—Wickwire Spencer Steel Co. A new loose-leaf handbook, describing various types of metal conveyor belts for high and low temperatures. This includes the new heavy duty "Alpha" link belt, "Delta" plate belt and spiral type. Bulletin N-37.

High Test Welding Rod—The Linde Air Products Co. A 12-page booklet describing the qualities and advantages of high test welding rod. Extensively used for fabrication of pipe lines, pressure vessels or other welding operations where high strength and economy are required. Bulletin D-63.

Ferro Alloys and Metals (Third Edition)—Electro Metallurgical Sales Corp. Describes current practices with specific reference to the "Electromet" products supplied to the metallurgical industry by this organization, together with suggestions for their use in both the ferrous and non-ferrous industries. Bulletin D-16.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin D-13.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin D-17.

Stainless Steels—United States Steel Corp. Booklet describing various stainless and heat resisting alloy steels produced by subsidiary companies. Tables of chemical compositions and physical properties are included, also recommended procedures for use, polishing methods, etc. Bulletin D-79.

Electric Heat Treating Furnaces—Ajax Electric Co., Inc. Photographic description of new electric furnaces for annealing wrought products, such as sheet, wire, tubing, rod, etc. Bulletin D-83.

Practical Metallurgy for Engineers—E. F. Houghton and Co., Philadelphia. A 435-page book by the Houghton Research Staff, covering practical metallurgy in all its phases. Copies of the third edition are obtainable by sending $3.00 directly to the above company.

The Coreless Induction Furnace in the Steel Industry—Ajax Electrothermic Corp. Reprint of a paper describing recent developments in high frequency coreless induction furnaces and their probable applications. Bulletin D-41.

Welded Construction Folder—Bethlehem Steel Co. Folder describing the use of rolled steel shapes and plates for the building of machinery parts by welding. The results are said to be sturdier construction, reduced weight, low cost, and elimination of patterns. Bulletin N-76.

Refractories—E. J. Lavino & Co. Literature on Kromepatch and Plastic K-N chrome ore refractories for industrial furnaces. Bulletin O-40.

Industrial Gas Heat—American Gas Association. A veritable textbook on the uses of gas heat in industry, profusely illustrated with photographs of installations, etc. Bulletin D-10.

Metal Progress, 7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as described under "Trade Pamphlets" in the January issue of Metal Progress. (Please order by number.)

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DEEP NITRIDING

(Continued from page 76) is subjected to the low nitriding temperatures — at which the hard nitrides of low diffusibility are formed — for about half of the total nitriding time, and is then heated progressively to the temperatures at which rapid inward diffusion of the nitrides of lower hardness takes place.

The upper temperature (1160° F.) is practically fixed, but the lower temperature varies with the case desired. Holding time at the lower temperature is some function of the total — it may be from 15 to 20% of the total nitriding time for that program.

Case hardnesses and penetrations are shown in the diagram on page 76 by curves *C* and *D*. It will be observed that the hardness at the very surface, the gradation of case, and the depth of penetration are capable of being controlled, according to the program adopted. Only a few of the possibilities are illustrated.

Conversely, if a certain case depth is desired, a suitable program can be set up to produce it in a shorter time. A case depth which formerly required 24 hr. to produce can be done in 16, with a worth-while saving in time, fuel, and ammonia. Moreover, as material of a lower core hardness (210 to 240 Brinell) can be used, machining will also be facilitated.

There are a few critical factors in the program method of controlling the nitriding cycle which, however, also apply to all nitriding cycles. The most important are:

(*a*) Responsive, accurate control of the work temperature; uniformity of temperature; and uniformity of distribution of the reactive gas throughout the load.

(*b*) An upper limit of 1160° F., beyond which nitriding cannot be done, nor can the work be held at the upper nitriding temperatures very long without loss in surface hardness of the finished part.

The improved method for controlling the nitriding cycle and its temperatures, briefly outlined above, enables the metallurgist to control the penetration, gradation, and hardness of case, extends the field for nitriding, and effects great savings in cost.